Document Title: Fundamentals of Forensic Pigment Identification by Raman Microspectroscopy: A Practical Identification Guide and Spectral Library for Forensic Science Laboratories

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Fundamentals of Forensic Pigment Identification by Raman Microspectroscopy: A practical identification guide and spectral library for forensic science laboratories.

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ACKNOWLEDGEMENTS

This manual represents one step further in what has been a six year process toward developing applications for Raman spectroscopy in our laboratory. This manual has come about thanks to NIJ funding for the past year, which has allowed us to assemble our first formalized effort toward systematically understanding pigment classification as it applies to pigment identification by Raman spectroscopy. Prior to this much appreciated NIJ funding, the prior years' work was internally funded by Microtrace and performed with the assistance of several summer interns, including Brendan Nytes and Jennifer Herb (now Microtrace employees), Bryn Wilke and Heidi Bonta. This research laid the groundwork to demonstrate that pigment identification is not only viable, but can be of benefit in actual casework.

Over the years, we have been provided regular assistance by Scott Ryland of the Florida Department of Law Enforcement and Ed Suzuki of the Washington State Crime Laboratory through courses they have taught our staff and for generously sharing pigment and paint samples, and most importantly for their kindness and willingness to share their extensive knowledge of all things related to paint and pigments. We also acknowledge the assistance that Gary Laughlin, Sebastian Sparenga, Meggan King and Kelly Brinsko from the McCrone Research Institute in Chicago have provided in the way of pigment reference samples from their collection.

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Finally, the rest of the Microtrace staff, including Jason Beckert, Mark Palenik and Katie White, have contributed to this work through their own research on colorants at Microtrace. They have also offered thoughtful comments in their review of this document.

Chris Palenik, November, 2011

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INTRODUCTION

Colorants (pigments and dyes) are everywhere. They color the paint on the walls surrounding you, the ceiling tiles over your head, and the tile or carpet below your feet. They are a significant component of paint, one of the more commonly analyzed types of trace evidence. There are several hundred pigments (and many more dyes) in commercial use, and more are being developed each year. In theory, they seem like an obvious material to exploit as forensic evidence; yet beyond the macroscopic color that a combination of colorants imparts to a material, the identity of individual pigments or dyes are largely ignored in forensic casework.

The reason for this is, of course, the small size and low relative concentration of pigments in a given application. Colorants are often present at levels near or below 1% in a finished material. Pigments are generally less than a micrometer in diameter, and when pigments can be observed microscopically, they are generally observed as an undispersed cluster rather than as individual particles (which may be below the resolution of the light microscope).

Successful efforts have been made to characterize select pigments in forensic applications by techniques such as powderX-ray diffraction (pXRD) (Curry, *et al.*, 1982; Rendle, 2003; Kotrly, 2006), Fourier transform infrared spectroscopy (FTIR) (Suzuki, 1997; Suzuki, 1999a-b; Suzuki and McDermot, 2006), X-ray fluorescence (XRF) and Energy Dispersive X-ray spectroscopy (EDS) (*e.g.*, Suzuki, 2006), visible microspectroscopy (Stoecklein and Palenik, 1998; Palenik and Stoecklein, 2003), polarized light microscopy (PLM), and microchemistry (Microchemical Methods at McCrone Research Institute). However, in all cases, each of these approaches has been subject to inherent limitations that have prevented widespread use of pigment evidence. The benefits and limitations of these methods will be discussed in more detail in a later section of this manual.

The discipline of art conservation has, by necessity, embraced pigment identification more aggressively than forensic science. Over the last forty years or so, polarized light microscopy and microchemistry have been established as important tools in this field (*e.g.*, McCrone, *et al.*, 1982). X-ray diffraction and transmission electron microscopy methods have also been more frequently used. In fact, this field (outside of focused academic and proprietary commercial research) has consistently provided the most general and accessible knowledge base of pigment identification (Feller, 1986; Fitzhugh, 1997; Eastaugh, 2004).

The development of Raman microspectroscopy has opened a new avenue for the possibility of identifying pigments in a consistent and reliable manner. Although the theory of Raman spectroscopy was established in the 1920's, it is only in the past two decades (or so) that reliable, commercially available analytical instruments have become available. With prices decreasing and reliability increasing, Raman spectroscopy has become an accessible technique for the interested forensic laboratory. In fact, the speed, minimal sample preparation requirements and power to identify a wide range of compounds suggest that Raman will only gain more and more use in forensic laboratories as applications are developed. The art community has already embraced this technology, and all major art conservation laboratories have at least one Raman spectrometer. While the art community has made great strides in developing Raman spectroscopy as a practical analytical tool for pigment identification, the needs and requirements of the art discipline differ enough from that of forensic science that our discipline is in need of its own systematic approach to pigment identification.

This leads to the purpose of this current work, which is to conduct the basic research in Raman spectroscopy that is needed to start to evaluate the potential benefits and evidentiary significance that Raman spectroscopy can provide to the forensic community. Prior to the NIJ grant that has supported this current work, Microtrace, along with several other laboratories throughout the world, have conducted a number of scattered studies focused specifically on forensic pigment identification. Topics have included ink (Mazzella and Buzzini, 2005; Palenik and Nytes, 2008), automotive paint (Suzuki and Carrabba, 2001; De Gelder, 2005; Palenik, *et al.*, 2008), and architectural paint (Palenik, *et al.*, 2009; Palenik and Bonta, 2008). For example, in a survey conducted on the Raman spectroscopy of a select group of automotive paints, Microtrace found that as many as four pigments could be identified in a single paint chip. All of these studies have shown that there is promise in the sub-discipline of Raman spectroscopy for the field of forensic science, but a systematic approach is needed to properly introduce this method as a more mainstream technique.

In order to begin to treat the topic of pigment identification in forensic science, it is, therefore, necessary to start at the beginning with a systematic approach to this topic. This manual has been prepared to relay the results of this initial research, in a practical context, to forensic scientists in a manner that would permit them to establish their own Raman spectroscopy laboratory and begin applying results of this research to actual samples.

The research can be divided into several sections which include:

- Background information regarding forensic pigment identification.
- The development of a reference collection and the chemical classification of pigments.
- Methods of analyzing pigments by Raman spectroscopy.
- Development of a pigment identification scheme.
- Examples of *in situ* pigment identification.

The approaches discussed in this manual have been written specifically toward the context of, and types of samples encountered in, a forensic investigation. At present, this manual represents the beginning of our approach to this topic and has focused on the basics of analyzing and classifying reference pigments. This research focuses specifically on organic and inorganic pigments, but does not attempt to treat effect pigments. We have applied for continuation funding, which would expand this manual to include more detailed information on the study of actual paint samples and the evidentiary significance of pigment identification.

IMPACT OF PIGMENT IDENTIFICATION TO FORENSIC ANALYSIS

With a working group dedicated to paint analysis (SWG-Paint), another group dedicated to compiling and analyzing paint samples (PDQ), and well established paint identification protocols in laboratories around the country, the question arises: what impact could the additional identification of pigments add to an already well established method?

There are several valid responses to this question. As a scientist (which should cover every forensic analyst reading this manual), there should be an inherent interest to explore new areas and push the limits of identification. More specifically, forensic scientists analyze and identify layer structure, binders, and even inorganic fillers, while pigments remain the only part of a paint system that is not routinely utilized in forensic paint comparisons. This is particularly unfortunate since there are presumably many more pigments and potential pigment formulations than there are binder formulations.

Finally, from a pragmatic point of view, Raman spectroscopy of pigments represents a novel way to conduct a fast analysis of a minute amount of paint with virtually no sample preparation. Of course, the questions that remain to be answered are whether Raman spectroscopy can identify a significant number of pigments in paint, and if that information can provide additional, or at least faster, discrimination than methods currently employed. While a single research project cannot fully answer these questions, this research project aims to build a foundation from which such questions can be addressed.

In the laboratory, there are two main categories of analysis in which pigment identification in paints could be of utility:

Comparative Analyses. These examinations probably make up the majority of paint analyses and consist of comparing a *questioned* sample to one or more *known* samples. In such cases, pigment identification could provide either a fast initial screening of evidence (faster than infrared spectroscopy) or potentially provide more evidentiary significance to the comparison of two paints in a full analysis. Logic would suggest that the identification of pigments in a comparative analysis (in which all other factors, layer structure, binder chemistry, and filler chemistry, are the same) would provide increased significance. Additional research, which is the subject of a continuation proposal, would be needed to address this latter question.

Investigative Analyse.: Paint formulations are generally made with a specific combination of pigments to achieve a desired color. In addition to color, pigments are selected for specific properties, such as color fastness (the ability to resist discoloration when exposed to environmental factors). For example, rutile is more commonly used than anatase in automotive paints due to its superior resistance to ultra-violet degradation. In cases where it becomes useful to identify a manufacturer or place constraints on the date of manufacture of a particular paint, the identification of the pigments in a recovered sample could hold information beyond what can be obtained from binder identification alone.

PRESENT STATE OF PIGMENT IDENTIFICATION

With the exception of a few research projects and occasional casework, there is very little true pigment identification being conducted in forensic laboratories.

Pigment identification by microscopy and microchemistry has been developed over the years and is taught in at least one forensic class (Advanced Forensic Microscopy: Paint and Polymers). Light microscopy (working at high magnifications or even with oil immersion) of a prepared thin section can help to identify the number of pigments, their size and relative concentration. Optical properties including birefringence and refractive index can help to identify, or at least constrain, the types of pigments present in a thin section. Figure 1 shows a thin section of a blue paint that contains several pigments (including blue and red organic pigments and two effect pigments). More specific identification of these pigments can be conducted using various microchemical tests. Despite having been established, these methods see little use in forensic labs today, in large part due to the high level of experience required of the examiner.

Energy dispersive X-ray spectroscopy (EDS) with a scanning electron microscope (SEM) and X-ray fluorescence (XRF) are commonly used to characterize the elemental composition of paints. From this elemental information, certain pigments or categories of pigments can be inferred. However, this is elemental and not chemical information, and therefore, pigments are not truly identified. For example, the presence of barium and sulfur might imply barium sulfate, while titanium and oxygen might imply titanium dioxide, and lead and chromium might suggest a lead chromate pigment is present. While these suppositions are often correct, it is never possible

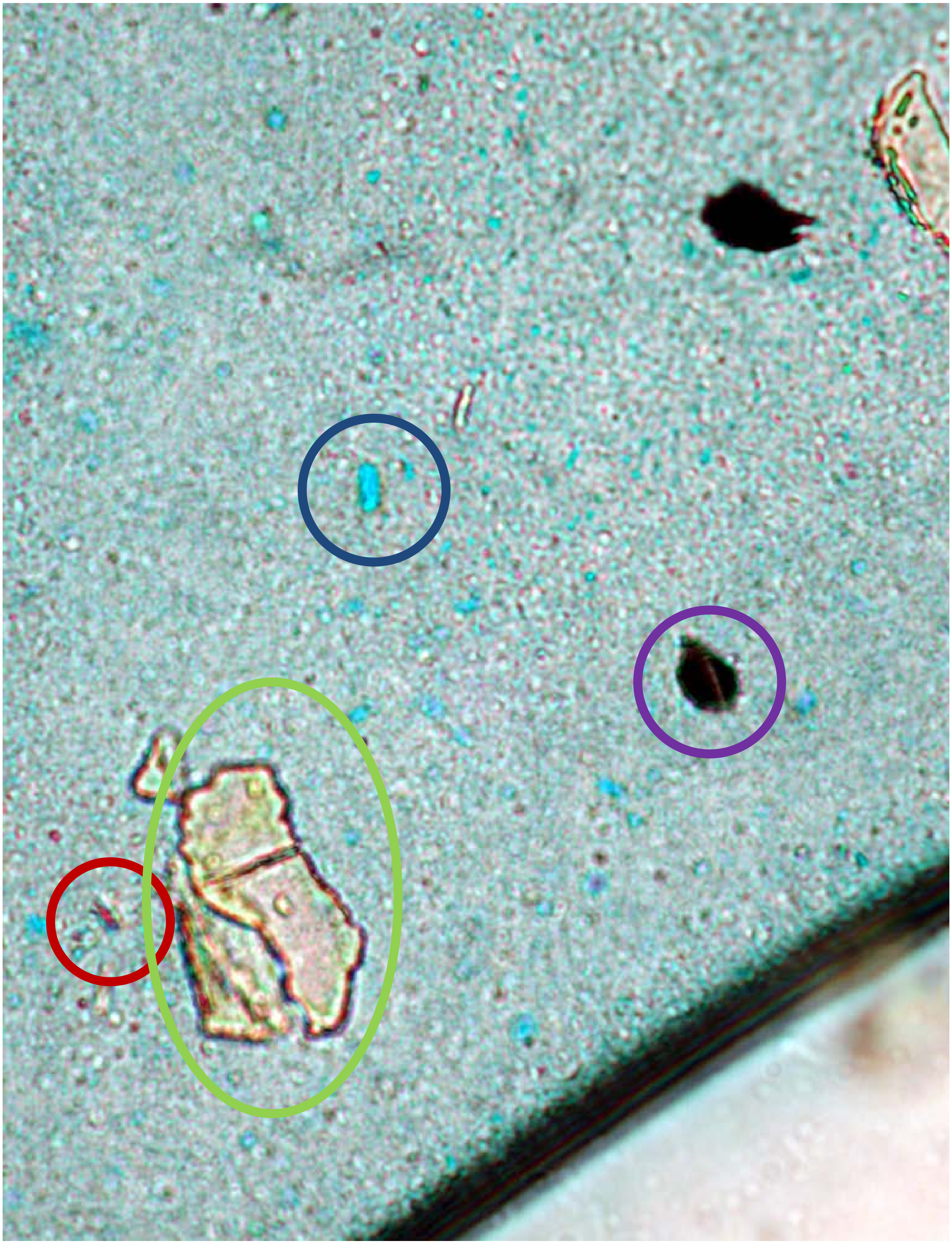


Figure 1. Thin section of a blue paint showing the presence of four different pigments observed in plane polarized transmitted light (mounted in xylene). Blue pigments (blue circle), with a varying size range, which dominate the paint. Red pigments (red circle), which are less commonly observed, and then two larger effect pigments such as mica (green circle) and an opaque metallic flake (purple circle)).

to know with certainty that a particular compound is present from qualitative EDS data alone. Furthermore, this type of classification leaves open questions such as: what polymorph of titanium dioxide is present or is lead carbonate also present?

To answer questions about the specific chemistry of the pigments in paint, scientists have tried methods to structurally or chemically characterize the pigments. Powder diffraction was applied by Curry, *et al.* (1982) to the study of several common paint pigments. While this information has proved useful in a number of our cases over the years, powder diffraction ultimately requires too large of a sample to be of any routine practical value in pigment identification.

In forensic labs, probably the most utilized method for pigment identification is infrared microspectroscopy. Suzuki (1997, 1998, 1999) has published extensively on identifying certain groups of pigments in the infrared spectra of various paints. While this method is useful for certain pigments, the concentration of many pigments is low enough that they are not detectable by infrared spectroscopy. Furthermore, the information present in infrared spectrum concerning pigments is simply not utilized by many conducting comparative analyses.

Outside of forensic analyses, virtually every industry that synthesizes, manufactures, or utilizes pigments has developed their own methods for characterization. It is outside the scope of this work to provide a full historical summary of these approaches; however, it should suffice to say the somewhat related field of art conservation (which is, on occasion, interested in art authentication) has been utilizing and developing pigment identification methods that are probably the most adaptable to forensic science.

In recent years, Raman microspectroscopy has become the most significant tool for pigment identification in the conservation world. There is a wealth of information on pigments and pigment identification in this field (Colour Index, 1971, 1982; Eastaugh, 2004; Herbst, 2004; Buxbaum, 2005). While all of the classical methods are still employed, Raman spectroscopy has become a standard method for identifying pigments. This technique can often be done *in situ* and is virtually non-destructive. Museums and other institutions have developed databases of pigments (UCL Raman Spectroscopic Library; Downs, 2006; Romanian Database of Raman Spectroscopy). In fact, at least one scheme for the identification of select organic pigments has been developed (Scherrer, *et al.*, 2009).

Generally, these databases focus specifically on artists' pigments and are limited in the number of samples they contain. Obtaining automotive pigments, which are often based on recent syntheses, is often more challenging than finding artists pigments, which can be purchased in small quantities from art suppliers. Furthermore, as we have found in our own examinations, these online pigment databases have not always verified the provenance of their pigments. For example, Beckert (2009) presented a talk about the pigment Indian Yellow. A reference spectrum from one online database was obtained that turned out to be a spectrum of tartrazine, rather than a salt (magnesium or calcium) of euxanthic acid (true Indian Yellow). This highlights the importance that any forensic development in this field must be based on solid reference material that has been verified.

RAMAN SPECTROSCOPY OF PIGMENTS

The concept of Raman scattering is based on a laser that is focused onto a sample, typically in a 1-2 µm spot. A small fraction of this energy is inelastically scattered by molecules in the sample. This scattering results from the interaction of the monochromatic photons with molecular vibrations in the sample, and as a result, the scattered photons have shifted in energy by an amount characteristic of a particular molecular vibration. The scattered light is collected by an objective (in a microscope system), projected onto a diffraction grating (in a dispersive system), which in turn, projects the scattered light onto an energy calibrated CCD. The resulting spectrum, produced by collecting the scattered light is measured in wavenumbers (similar to infrared spectroscopy), but relative to the energy of the laser (rather than as an absolute value, as in infrared spectroscopy). Therefore, the abscissa of a Raman spectrum is denoted as a Raman shift and is plotted in delta wavenumbers (Δ cm^{-1}). The above description is meant as a brief overview of Raman scattering, which is treated in rigorous details elsewhere (*e.g.*, Corset and Turrell, 1996).

Raman spectroscopy is often introduced as a technique that is "complementary" to infrared spectroscopy. This is not an unfair statement, as often, molecules that produce poor infrared spectra, often produce excellent Raman spectra; however, it does not capture all of the benefits that Raman spectroscopy can offer as a practical analytical technique. For example, in our lab, we have found that Raman spectroscopy often serves as a suitable replacement for powder diffraction, when we are looking to identify inorganic phases, but do not have enough sample for a pXRD analysis.

For pigment analysis, one of the major benefits of Raman spectroscopy is that pigments, which are either poor infrared absorbers or often are not present at high enough concentrations to be detected, often provide excellent Raman spectra with sharp peaks. An added benefit is that most binders in automotive paints contribute very little (if at all) to the Raman spectrum of the paint.

Raman spectroscopy also permits samples to be studied *in situ*, and often with little or no sample preparation. In fact, we have found that Raman spectra of at least fair quality can be collected through the clear coat of an automotive paint. With a thin section, confocal Raman microscope systems can be used to probe particles approaching the size of a single pigment (or at least a pigment cluster). In theory, this would permit examination of minor pigment components that can be observed by light microscopy (such as those in Figure 1).

Of course, if Raman spectroscopy was truly this simple, it would have been utilized in forensic labs for years. Prior to about 2000, Raman systems were largely (though not exclusively) built in-house, required extremely expensive lasers, were slower, and required frequent and time consuming alignment processes. With the expanding market for CCD chips, advances in laser technology, improvement in processor speeds of desktop computers, and the introduction of infinity optics, Raman spectroscopy developed into a reliable and accessible laboratory method. These advancements continue to improve the user-friendliness of the technique to this day. It is important to note, however, that with these improvements have come a much larger number of companies that manufacture Raman instruments (from handheld, to macro, to micro, and others). When configuring a system, there are a wide range of available parameters to select from, and also wide ranges of quality (both in terms of the instrument and the software).

So with good systems, the question remains, why has Raman not gained a wider foothold in forensic science, and particularly paint examination? As mentioned above, one reason is momentum. Forensic labs have set protocols, which are often not pleasant to modify unless a known improvement is gained. The benefits of Raman spectroscopy are not fully known, and are one of the purposes that this research is aiming to define. Another reason Raman spectroscopy is not utilized is fluorescence, an inherent feature of many pigments and samples, which effectively swamps the Raman scattering. Fluorescence is often discussed, but is not particularly well understood, either in terms of its practical effects on sample analysis or its ability to be theoretically predicted.

As will be discussed later in this manual, there are several methods to attempt to get around fluorescence, which include, using an alternate laser, photo bleaching the sample, or in the case of one instrument, slightly altering the laser wavelength between two collections in an attempt to define and subtract the background. All of these methods have strengths and weaknesses; certainly none is perfect. Fluorescence remains a limitation of Raman spectroscopy – the extent to which it is an issue for paint samples is still being determined.

Another way around fluorescence, at least in certain samples (including many common dyes), is a technique known as surface enhanced Raman spectroscopy (SERS). The technique uses a metal colloid or a metal substrate that is brought into contact with the analyte. The metal plus analyte complex results in an extremely strong SERS signal that can be several orders of magnitude stronger than a regular Raman spectrum. A commonly cited example of the extreme sensitivity of SERS is a research study which purportedly used SERS to detect single molecules (Nie and Emory, 1997).

REFERENCE PIGMENT COLLECTION AND ORGANIZATION

Our laboratory has invested significant internal resources to build world class collections of a wide range of forensically interesting reference samples. These collections include fibers (> 3000 samples), human and animal hairs (> 2000 samples), pigments (> 1200 samples), dyes (>5500 samples), glass (>500 samples), sand and soil (>1500 samples) wood, pollen, and polymers. These physical samples have played important roles in numerous cases in which we have been involved, and they have helped us to stay abreast of current trends in manufacturing and development, particularly as it applies to the examination of trace evidence.

In proposing and starting this research project, we realized it would be helpful to have the largest possible database of pigments. However, until we began characterizing and organizing the samples in our study, we did not fully understand why this is so critical. The significance of this physical pigment reference collection is that it represents, to the best of our knowledge, all major chemical groups of organic pigments that are known. We have also included in this work a range of inorganic pigments as well (however the latter are of more interest to the art community, and are thus not the focus of this work). Representing all major classes of pigments is significant in that, when identifying a pigment, it is not sufficient to have only a matching spectrum, but it is of nearly equal importance to know which (if any) other pigments have a similar spectrum. Some pigments, as will be discussed in the classification scheme, can be identified specifically (*e.g.*, PR 49:1 and PR 49:2 or PR 48:1, PR 48:2, PR 48:3, PR 48:4). Other pigments can only be identified to a certain chemical group (*e.g.*, diarylide, disazo condensation, etc.). This information defines the specificity of the identification and has a likely impact on the evidentiary significance of the identification.

While the spectra and identification scheme provided should be of utility to any laboratory, there is never a true substitute for the knowledge and experience that can be gained by examining and identifying pigments from your own physical sample collection.

PIGMENT NOMENCLATURE

PIGMENTS, DYES AND LAKES DEFINED

Before getting into pigment naming and classification, it is important to first understand the difference between a pigment and a dye. The term colorant is used to define a material that when added to a substance, changes the color of that material. Colorants consist of dyes and pigments. Dyes are compounds which are soluble and chemically bond to the material to which it is applied. Dyes, therefore, are not visible as discrete particles. Pigments are solids which alter the color of the material with which they are combined. As opposed to chemically bonding with the substrate, pigments remain as discrete, solid particles (typically on the order of less than 1 µm). Certain chemical compounds can be found as either a pigment or a dye, depending on its use. For example, PB 66 is also listed as Vat Dye Blue 1 (*i.e.*, Natural Blue 1). Lake pigments consist of a dye that it adsorbed onto an inert compound (typically a metal salt), allowing a dye to be used as a pigment. Commonly lake pigments are adsorbed onto aluminum hydroxide, barium sulfate and a variety of other metallic salts. Pigment Red 48:1, a beta oxynaphthoic acid, is one example of a lake pigment that was analyzed in this work.

COLOUR INDEX CLASSIFICATION

Prior to 1925, there was no formal organization of pigment nomenclature, and pigment names were either historical or given by a manufacturer. As such, multiple names often existed for a given pigment, and a given name might not represent only a single chemical formula. In 1925, the first Colour Index (C.I.) was published with the purpose of assigning each colorant molecule a unique identifier, thus providing a means by which to categorize colorants and provide structural, solubility and various manufacturing details. The Colour Index has gone through three print editions and the fourth edition is now available as an online resource that is updated as new pigments are submitted. It is important to note that new chemical structures are often unpublished as they are considered proprietary or confidential by the manufacturer.

There are several features of the Colour Index with which anyone concerned with the identification of colorants should be familiar. The following descriptions are taken from or paraphrased from the Colour Index International document "Colour Index Generic Names, Constitution Numbers and the use of Colon Numbers."

C.I. Generic Name. "a classification name and serial number which when allocated to a commercial product allows that product to be classified within any Colour Index Application Class." The generic name is familiarly listed as C.I. Pigment Yellow 74, Pigment Yellow 74, or simply PY 74. The generic name represents a single chemical compound that might be made by multiple manufacturers. The exceptions to this are "crystal modifications" (*i.e.*, polymorphs) and in cases where a colon is used (as discussed below).

C.I. Constitution Number. A constitution number is assigned to a colorant when the chemical constitution (*i.e.*, composition) is disclosed for publication. The C.I. constitution number has traditionally been a five digit number, but since 1997, six digit numbers have been assigned.

Colon Numbers. In certain instances, a C.I. Generic Name or C.I. Constitution Number is followed by a colon and an additional digit. It is important to note that a "Colon Number" following a Generic Name does not necessarily coincide with those attached to a corresponding Constitution Number.

Generic Name Colon Numbers. These include colorants that differ slightly (typically chemical or polymorph differences). These colon numbers have not been always applied consistently, but the system is still used to group certain colorants.

Constitution Number Colon Numbers:. This includes colorants "where dyes or pigments differ only in the metal or acid used for salt formation." For example PR 48 (C.I. 15865) is the sodium salt and PR 48:1 (C.I. 15865:1) is the barium salt. The use of a six digit Constitution Number has made it possible to minimize the inconsistencies of the colon numbering scheme.

There is a great deal more subtlety to these definitions, and anyone attempting to gain a full understanding of pigment nomenclature would be well served to read the source document and examine the C.I. colorant entries in greater detail.

PIGMENT DATABASE

Microtrace and its scientists have been collecting physical colorant reference samples for at least the past thirty years. This collection has grown to include approximately 1200 pigment and >5500 dye samples. This includes over 300 unique organic and inorganic pigments (not including effect pigments). Over the past six years, this collection has been organized in a relational database to include information about the pigment and any accompanying analytical data that we have acquired.

DATABASE METADATA

Here we present a list of the metadata (data accompanying our pigment data) that we maintain with each colorant entry in our database. We provide this information for two purposes: first, since the pigments from this database have been utilized to produce reference spectra, the accompanying data is important to verify source and to ensure that the pigment in question is consistent with its name. Second, we cannot stress the significance of producing and maintaining an "in house" physical reference collection. We offer this data as a starting point for developing and maintaining information about your own laboratory collection.

The following fields are maintained:

Table 1. List of metadata maintained in the Microtrace Colorant Database

Metadata	**Description**
Ascension Number	Unique internal sample number.
C.I. Generic Name	*e.g.*, - C.I. Pigment White 6 (Rutile)
C.I. Constitution Number	*e.g.*, 77891
Chemical Name	*e.g.*, Titanium Dioxide
Chemical Composition	Chemical formula (*e.g.*, TiO_2)
Structure	Image of the chemical structure.
CAS Number	13463-67-7
Molecular Weight	79.90
Synonyms	Trade name and or chemical synonyms (*e.g.,* Titanium White).
Chemical Category (C.I.)	For organic pigments, this is the chemical group to which C.I. assigns the pigment.
Chemical Category (Modern)	Microtrace, in conjunction with various published texts, has developed its own internal classification based on pigment chemistry.
Nominal Color	A qualitative classification of the colorant's color into one of fourteen color groups.
Manufacturer	The manufacturer of a pigment, when known.
Trade Name	The specific trade name or number used by the manufacturer as a descriptor.
Manufacturer's Color	The specific color name used by the manufacturer.
Source	The organization or person from which the pigment sample was supplied.
Authentication Letter	Information supplied with a pigment sample that assists in verifying the ultimate source of the pigment.

DEVELOPMENT OF A "QUALITY INDEX" METRIC

Anyone who has ever tried to build an authenticated collection of anything will find that obtaining authenticated samples is not only difficult, but sometimes impossible. Therefore, many of the samples that make up the collections in our laboratory are "samples of opportunity" – meaning that we take whatever samples we can find. The amount of information that comes with these samples can vary. In the best of circumstances, we receive pigments directly from the manufacturer, along with all supporting information about that pigment and a letter or label from the manufacturer that proves the source. At the other extreme, we occasionally receive nothing but a vial labeled with a pigment name from some third party source. In that we often have samples of the same pigment from various sources, we found it prudent to develop a way to objectively rank the quality of authenticity of each pigment. The resulting "Quality Index" is a rank we have devised to objectively judge the lineage of each reference sample in the collection. It is of critical importance to realize that the Quality Index is not an indication a pigment is or is not what its label purports it to be, but rather a judgment about what is known of the pigment's source.

The concept of a ranking scheme was inspired by the powder diffraction community, which has its own quality index to rank the quality and confidence they have in their published diffraction patterns. While not directly applicable to this work, it is the concept of this system that inspired our classification scheme.

The “Quality Index” developed here is designed to allow for an unbiased assignment of a number (1-5) to define the “quality” of a reference pigment’s lineage. A Quality Index of “1” indicates that the highest degree of supporting information is associated with the particular pigment. Conversely, a Quality Index of “5” suggests that very little information is known about the reference sample (outside of the pigment’s name). The criteria for assigning a Quality Index are provided in Table 2. Again, it is important to remember that a pigment with a Quality Index of “5” is not necessarily inaccurately labeled, but rather that it does not have the supporting documentation that might accompany a pigment obtained directly from the manufacturer.

Due to confidentiality agreements or understandings in place with our various pigment sources, we cannot provide specific information about the manufacturer or source. However, the Quality Index ranking can be used to understand the level of provenance associated with any pigment presented in this work.

Table 2. Criteria for assigning a Quality Index (Q.I.) value to a pigment reference sample.

Q.I.	Pigment Source	Pigment Name	Authentication Letter	Source	Manufacturer
1	Directly from pigment manufacturer	K	K	K	K
2	Secondary source (*e.g.*, pigment distributor)	K	K	K	K
3	Secondary source	K	U	K	K
3	Secondary source	K	K	U	K
4	Other source	K	U	U	K
5	Other source	K	U	K	U
5	Other source	K	U	U	U

K = Known or Present; U = Unknown or Not Obtained

PIGMENT ROSTER

From our database of approximately 1200 pigments, a subset representing a roster of the unique organic and inorganic pigments comprising this database was selected; this selection includes 190 organic pigments and 78 inorganic pigments. This set represents a significant majority of the commonly available organic pigments, and spans all major chemical categories of pigments. Thus, if a specific pigment is encountered that is not in the database, it is likely that the analyst will be able to characterize the pigment to some extent. Although this database represents a smaller fraction of the inorganic pigments that are produced, those that are most widely used in consumer applications are represented. The conservation field community can be consulted for data on inorganic artistic pigments.

A list of the unique pigments analyzed in this work is presented in Appendix A. This Appendix lists pigments by chemistry and contains basic information about each pigment including: C.I. Generic Name, C.I. Constitution Number, CAS number, the Microtrace pigment number, the Quality Index rank and a common name. As discussed in the Quality Index section of this manual, the manufacturer and trade name information has not been provided due to agreements with various pigment suppliers. Due to the fact that C.I. Constitution Numbers generally represent a single compound, pigments from different manufacturers should have the same reference spectrum. We have found this to be the case, as detailed in the sub-section "Verification of Pigment Identity."

RAMAN SPECTROSCOPY OF PIGMENTS – BASIC RESEARCH

The research topics discussed in this section arose while determining the parameters necessary to collect and verify the spectral reference data that represents the main focus of this research. The results published here should be of guidance to any forensic laboratory looking to introduce or validate Raman spectroscopy as an analytical method.

The tasks explored include: the examination of sample substrates; the effects of varying laser power on spectra; "day-to-day" reproducibility of reference spectra; investigations into the homogeneity of reference material; examinations into noted variations among spectra from samples with the same C.I. Generic Name; and the use of orthogonal methods and other means toverify the consistency of pigment labels. When applicable, the above tasks were investigated using the same five pigment samples (Anatase, Rutile, PB 15, PR 224, and PY 74)

SAMPLE SUBSTRATES

In preparing reference samples, an ample sample volume is generally available such that the underlying substrate does not have an effect on the produced reference spectrum. To verify this, it is important to have reference spectra of any substrates that are used. Prior to collecting reference spectra, several substrates were evaluated to determine which substrates were preferable. In the end, it was found that a thick enough reference sample makes the substrate irrelevant; however, the data collected during this experiment still has implications for substrates when examining casework samples.

Five substrates were evaluated: carbon tape, polished beryllium, soluble adhesive, sheet glass and polished aluminum. The spectra collected from these are presented in Figure 2. A list of peaks in each of these substrates is presented in Table 3.

Table 3. Raman peak positions of various sample substrates.

Substrate	Major (Δcm^{-1})	Minor (Δcm^{-1})
Carbon Tape/Carbon Stub	1610 and 1310 (broad)	2620 (broad)
Beryllium Plate	460	None
Soluble Adhesive*	2245, 1740, and 1450	2900 (broad)
Glass Slide	1855 and 1365 (broad)	None
Aluminum Slide	None	None

* Soluble adhesive was used to mount samples on the beryllium plate.

The affects of these substrates on the reference spectra of the five studied pigments is shown in Figure 3. It is important to note that all of these peaks are minor, but they are notable when the interference is observed. We have found that aluminum slides are the best overall substrate for general Raman spectroscopy since there are no interfering peaks. The beryllium plate with soluble adhesive and the glass slide were eliminated as suitable

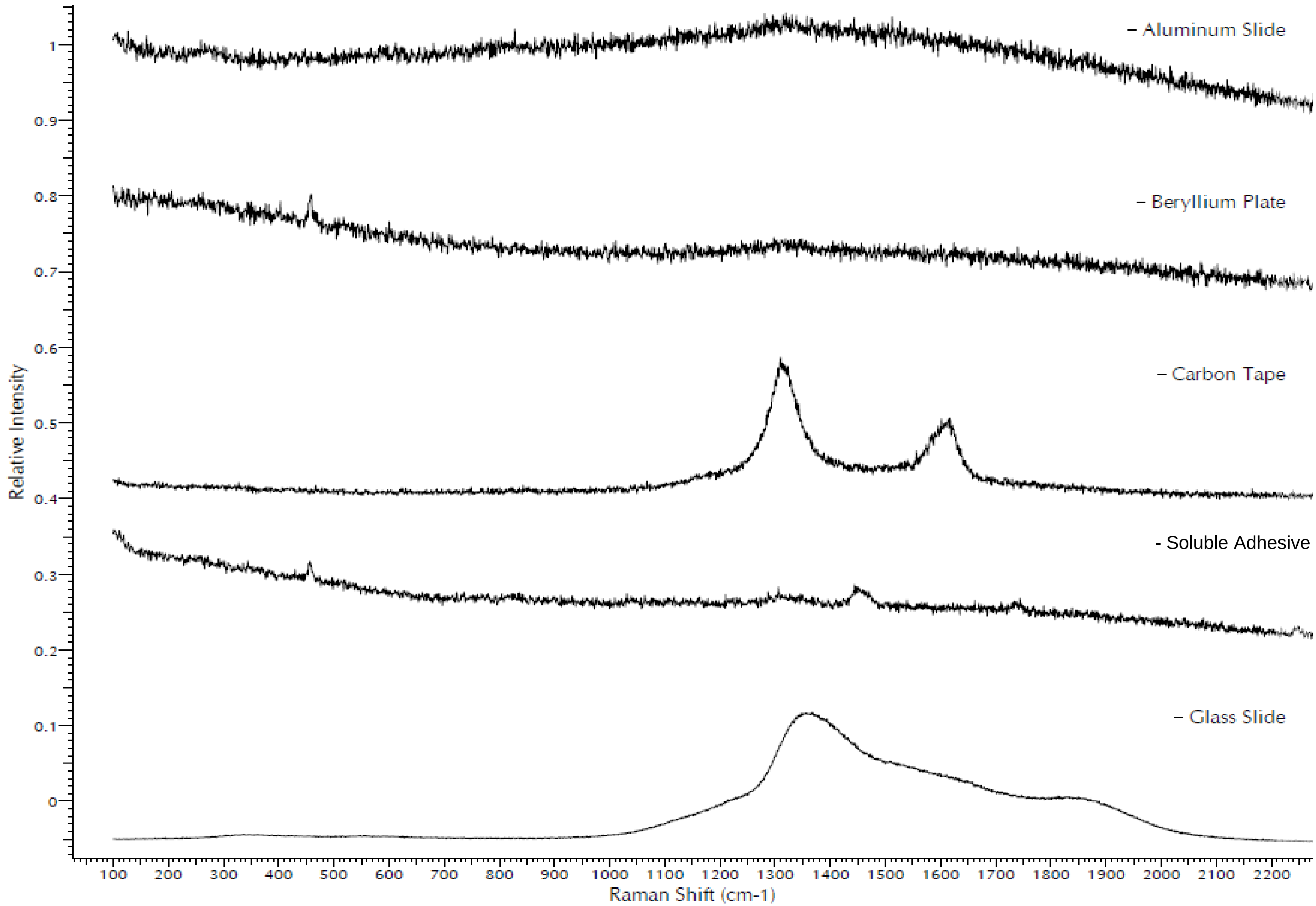


Figure 2. Raman spectra of the various substrates evaluated.

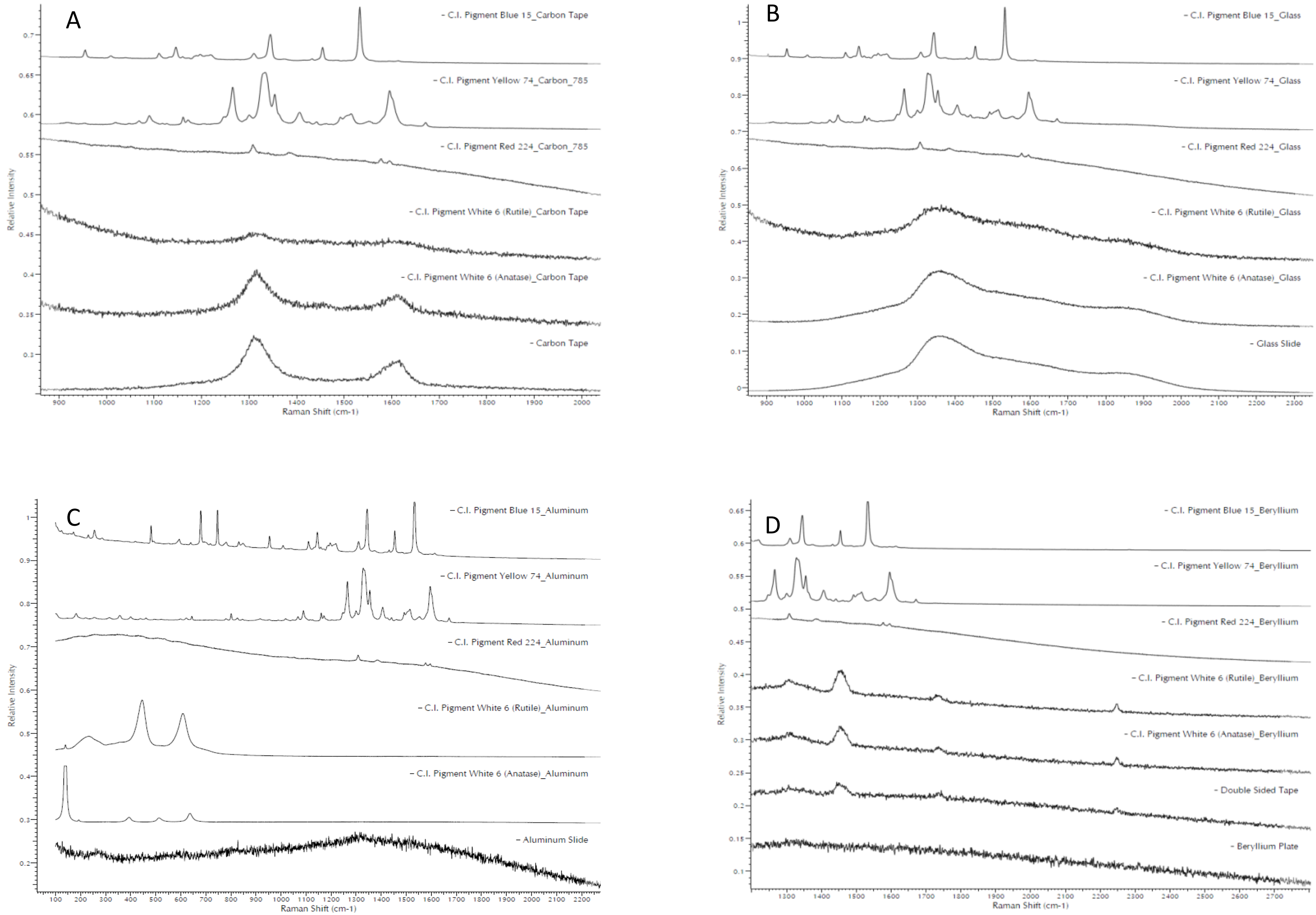


Figure 3. Raman spectra of five pigments on four different substrates. A) Carbon tape; B) Glass; C) Aluminum; D) Polished beryllium.

substrates for this work. Such substrates can be still be used for analysis; but just as preparing a Nujol mull produces interferences in an IR spectrum, users must be aware of the potential interferences from whatever substrate they select.

For the purposes of this work, pigments were mounted on carbon tape, which was mounted on an aluminum slide. This permitted examination of the samples by both Raman spectroscopy and EDS in the SEM. Care was taken to use thick enough samples that the amorphous carbon contribution was minimized or eliminated.

EFFECT OF LASER POWER ON REFERENCE SPECTRA

It is standard practice to maintain a record of the laser power at the sample at the focal plane. This can be achieved easily using a hand held laser power meter. On the system used in this work, the laser power at the sample is controlled by a series of neutral density filters. The relative laser power could be selected as one of sixteen increments between 5×10^{-7}% and 100%, which represented a laser power range of 8×10^{-4} mW and 143 mW (for the 785 nm laser).

Introductions to Raman spectroscopy are often accompanied by stories of burned samples, or even samples that have ignited. We have observed these events in our laboratory as well; however, they can be minimized, if not completely eliminated by carefully selecting an appropriate laser power. We have found that for most (if not all) pigment samples, the detector will saturate long before any visible sample charring or burning begins. Based on this, it is fair to say that Raman is a non-destructive technique. Furthermore, Raman spectroscopy can utilize such a minute amount of material (less than infrared spectroscopy) for analysis that even if the analyzed fragment or area is damaged or destroyed, the effect on most samples is not noticeable.

One goal of this work was to determine the optimal power range for examining the pigment reference samples. To do this, each of the five pigment samples listed at the start of this section was analyzed at a series of increasing laser powers until the detector was found to saturate. The laser power just below saturation was determined to be the optimal power. Table 4 lists a matrix of pigments versus laser power and illustrates the optimal laser power for each of the pigments studied. Powers in this range were then commonly used for examining the samples in this work. It is of significance to note that these findings were only used as a guide, and are not meant to be hard and fast rules.

Table 4. Results of experiments to determine the laser power range to use for studying reference pigments. Optimal powers are labeled in green.

	Laser Power (mW)							
Pigment	**19.25**	**9.16**	**6.01**	**2.93**	**0.83**	**0.39**	**0.012**	**0.007**
Anatase	S	S	S	O	U	U	U	U
Rutile	S	S	S	O	U	U	U	U
PR 224	S	S	S	S	S	O	U	U
PY 74	S	S	S	O	U	U	U	U
PB 15	S	S	S	S	S	O	U	U

* S = Detector Saturated; O = Optimal Power; U = Detector Unsaturated

One unexpected effect that was observed when examining Raman spectra collected at different powers was a measurable broadening and shift of Raman peaks with varying laser power. No new bands were noted as the laser power was changed (as would be expected); however, the band position and band width did vary with laser power for each pigment. The pigments examined showed broader peaks and wavenumber shifts with increasing laser power. For example, in PY 74, a discernable doublet merged into a single broad band (Figure 4).

The homogeneity study performed (discussed below) confirms this trend is not a result of sample heterogeneity, but rather an effect of the laser power. The observed broadening and peak shifts may be due to laser-induced heating. In PB 15, for instance, up to a laser power of 0.012 mW, the Raman band position and band width remained nearly unchanged. When the incident laser power is increased to 0.83 mW, the strongest peak saturates and other peaks shift as much as 4 cm^{-1} (Figure 5). When the laser power is reduced to 0.007 mW, the peaks are observed in their original positions. This shows the shift was not permanent and a reversible shift in either direction could be observed by increasing or decreasing the laser power.

Despite the observed changes in peak position, the actual impact of this result is negligible on qualitative identifications, as a peak shift of a few wavenumbers, will not, in the great majority of cases, result in an ambiguity in the identification scheme presented below or in spectral searches.

SPECTRAL REPRODUCIBILITY

On thirty separate days (over a period of nearly two months), reference spectra were collected from the five pigments listed previously. Spectra were collected from the same preparation following our typical instrument warm-up period of thirty minutes and our daily wavenumber calibration process (conducted on a silicon reference). The data from these spectra were interpreted to determine the spectral reproducibility.

All of the spectra have been collected and the data have been evaluated to determine the extent of peak shift over these time periods. The tabulated data from these spectra are presented in Table 5.

Table 5. Spectral reproducibility results based on 30 measurements of each pigment spectrum conducted on 30 separate days.

Pigment	Nominal Peak (Δcm^{-1})	Average Position (Δcm^{-1})	Position 3σ (cm^{-1})	FWHM (cm^{-1})	FWHM 3σ (cm^{-1})
Anatase	144	143.9	2.0	16.5	3.6
Rutile	443	442.6	3.4	40.8	4.1
PR 224	1308	1308.0	2.2	4.9	5.1
PY 74	1333	1332.6	1.3	20.4	0.5
PB 15	1532	1532.4	1.7	8.5	4.5

The variation in the average position, based on 3 standard deviations (3σ) is generally less than 2 cm^{-1}. The sole exception is rutile, which has a 3σ of 3.4 cm^{-1}. It is important to note that the rutile peak examined is also the broadest peak examined (100% greater full width at half maximum (FWHM) than the next widest peak). Regardless, all of the observed variation is within the effective resolution of our system (~3 cm^{-1}). This illustrates the spectra maintain an acceptable reproducibility over time.

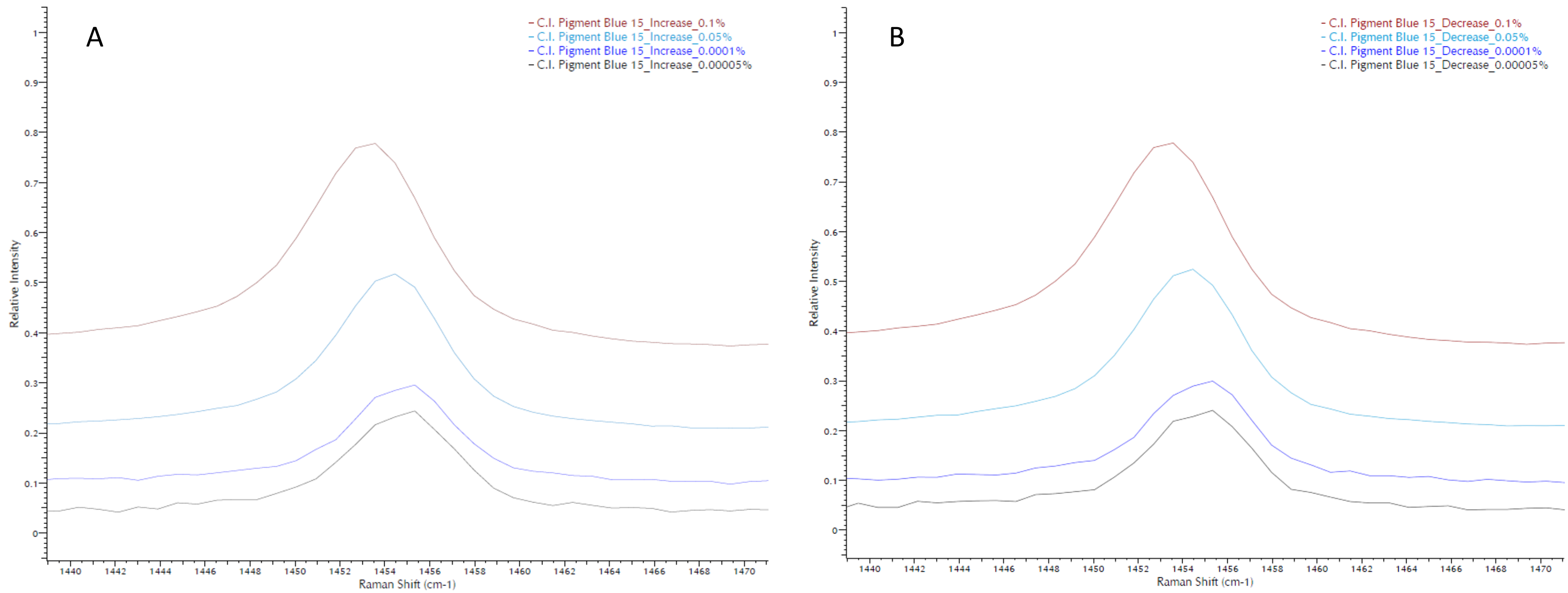


Figure 5. Raman spectra of PB 15 at varying laser powers. A) Laser power increasing from 0.007 mW (lower, black) to 0.83 mW (upper, red). B) Laser power decreasing from 0.83 mW (upper, red) to 0.007 mW (lower, black) .

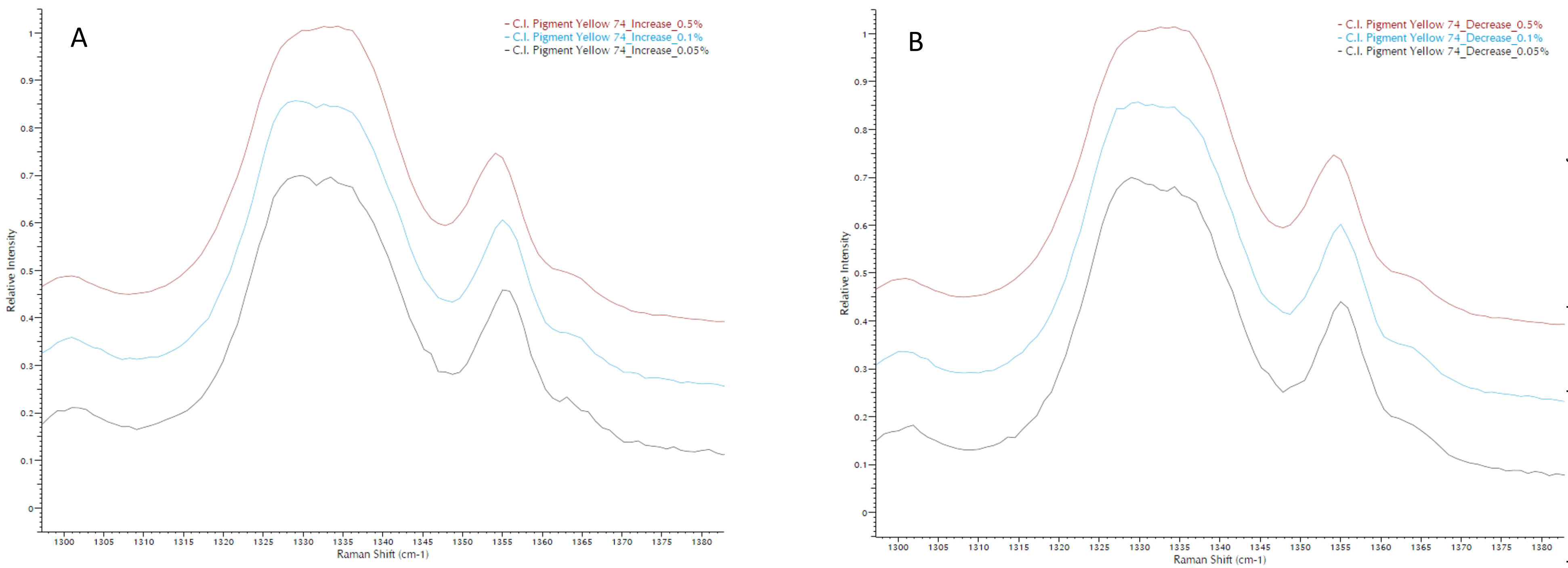


Figure 4. Raman spectra of PY 74 at varying laser powers. A) Laser power increasing from 0.39 mW (black) to 2.93 mW (red). B) Laser power decreasing from 2.93 mW (red) to 0.39 mW (black) .

SAMPLE HOMOGENEITY WITHIN A SINGLE REFERENCE SAMPLE

Raman spectroscopy, like infrared spectroscopy, is sensitive to the major components within the analytical volume. Therefore, unlike XRF or Inductively coupled plasma mass spectrometry (ICP-MS), where slight variations in the elemental composition of the sample are readily detected, Raman is sensitive to only the major components in the analytical volume sampled. This is not to say that Raman spectroscopy is not sensitive; however, the sensitivity of Raman spectroscopy is based on its small sampling volume, rather than the sensitivity of the spectrometer. The exception to this is SERS.

Is a reference sample homogenous? Of course, the answer to this question is that it depends on the quality of the sample. Nonetheless, the question we can address is whether the five reference samples examined in this section contain internally detectable differences by Raman spectroscopy. As will be discussed later in the verification section below, reference pigments are not composed entirely of pigment. Even pigments obtained directly from manufacturers contain other components, which are added to achieve certain physical properties.

Ten subsamples were collected from each of the five pigments listed above. The most significant result is that no additional peaks were identified in any of the sub-samples studied. Of secondary interest is that the peak positions and peak widths were similar to those presented in Table 5.

RAMAN REFERENCE SPECTRA

Raman spectra were collected from a subset of our pigment database that represents all unique inorganic and organic pigments in our collection. This section of the manual describes the parameters and approach developed for data collection and verification. The actual collected spectra are presented in Appendix B.

COLLECTION METHODS

The methods described below were developed specifically for collection of pure reference pigments. Slight modifications to these methods are necessary for the analysis of pigments in a sample matrix. The approaches to sample collection developed (thus far) are discussed in more detail in the "*In situ* Analysis" section.

INSTRUMENT SPECIFICATIONS

The following specifications and options were utilized for data collection in this research project. The authors have utilized a wide variety of Raman instruments and have found that the specifications presented below represent a reasonable balance between performance and speed. Due to the fact that Raman spectroscopy is a relatively new application in forensic science, these specifications are presented as a starting point, rather than a hard rule. It is certain that other configurations can be utilized to produce similar results. Only with a community of scientists utilizing these methods on a regular basis will it be possible (or even necessary) to critically evaluate and specify instrumental parameters more specifically.

The instrument used in this research is a Renishaw InVia Raman dispersive microspectrometer with the following specifications:

- Lasers: 785 nm (diode), 514 nm (Ar ion)
- Gratings: 1200 lines/mm (used with 785 nm); 1800 lines/mm (used with 514 nm)
- Laser power: 0.01 – 6 mW (785 nm, at sample)
- Spot size Diameter: 3 µm x 30 µm (line) or ~1-2 µm (spot)
- Confocal Volume: ~3 μm^3 (785 nm laser)
- Spectral resolution: ~3 cm^{-1}
- Spectral range: 100 – 3500 Δcm^{-1} (used for pigment interpretation)

Stage and spectral mapping options continue to improve. While we have found little practical use for mapping results, there are some mapping applications that effectively improve data collection times over traditional point analyses.

INSTRUMENT VALIDATION

The following aspects of a Raman microspectrometer system should be established. For the purposes of this work, the following parameters are verified on a regular basis:

- Wavelength Calibration: Verified on a daily basis
- Spectral resolution: Verified on a yearly basis
- Spot size location: Verified on a daily basis
- Spot size: Verified on a monthly basis
- Laser power (at sample): Verified on a yearly basis

The frequencies listed above were determined in our laboratory as reasonable for the variations we have observed. In general, procedures for conducting these verifications or instructions for making alignments to optimize these parameters can be supplied by the instrument manufacturer.

REFERENCE SAMPLE PREPARATION

Pigment reference samples were prepared for analysis by placing a small amount of each sample on a strip of carbon tape that was mounted on a polished aluminum slide. Each pigment was placed on the carbon tape using a tungsten needle. The needle was also used to disperse and smooth the pigment (a flatter region is easier to focus on by Raman, creating a stronger signal). The samples were prepared in this way to permit both Raman analysis and SEM/EDS analysis. See the sub-section on Sample Substrates for more detail on the substrate selection and its potential contribution to the sample spectrum.

SPECTRAL ACQUISITION

The microscope is focused on the surface of a given pigment reference sample. The spectral acquisition time was held fixed at 10 seconds; however, the laser power and number of accumulations varied from sample to sample.

The number of accumulations was increased in order to improve the signal-to-noise ratio. When multiple accumulations are collected, the system co-adds the intensity data at each wavenumber bin. Multiple accumulations improves the signal of a weak peak without saturating stronger peaks, whereas increasing the laser power or exposure time will generally serve to saturate the detector (for stronger peaks) or increase fluorescence.

Fluorescence occurs unpredictably in samples. The strength of fluorescence (and the strength of Raman scattering by the sample) will dictate whether all, some, or no peaks will be visible in the Raman spectrum. When it occurs strongly, the detector will saturate and no peaks will be visible. Depending on the balance between the strength of sample scattering and strength of fluorescence, the Raman bands from the sample may or may not be visible. Generally, only the major peaks will be obvious. In such cases, the background can be baseline corrected, which permits even a moderately fluorescing sample to be searched against a database. Overall, fluorescence can probably be considered the Achilles' heel of Raman spectroscopy. There are several ways to deal with fluorescence that could serve to reduce it:

> *Reduce the laser power.* Reducing the laser power can reduce fluorescence in the sample.
>
> *Sample bleaching (quenching).* By exposing the analytical area to the laser for a period of time (minutes to an hour, typically), the fluorescence background will often be reduced, thereby improving the signal to noise ratio of the sample.
>
> *Confocal mode.* Reducing excitation volume can reduce fluorescence in the sample.
>
> *Excitation laser.* Changing the excitation (laser) wavelength being used can help with fluorescence. In general, excitation sources closer to the IR region are less susceptible to fluorescence than those approaching the UV.

POST PROCESSING

All spectra collected are manually evaluated to determine what, if any, post processing is needed. A copy of all raw data is always saved; however, spectra are almost always baseline corrected. The most common exception to this is when the fluorescence of a spectrum is so strong that no Raman scattering is observed. In this case, the fluorescence spectrum is provided with no spectral processing.

Smoothing is the only other operation that is applied to spectra with extreme levels of noise or fluorescence. Smoothing improves the signal-to-noise ratio, but degrades the spectral resolution. Smoothing should not be used as a substituteto obtain a better measurement.

SPECTRAL ARTIFACTS

A variety of spectral artifacts can be encountered during analysis.

Cosmic Rays. Cosmic rays are random, high energy particle events originating from space. CCD detectors can be affected by these particles, which manifest themselves as sharp, random peaks in a spectrum. Most instruments have automated removal algorithms in their software that reject these rays (often through collection of multiple spectra).

Monitor peaks. Many Raman systems are in enclosures to protect the user from stray laser radiation. An added benefit of an enclosure is to protect the spectrum from stray light. The microscope objective has a high collection efficiency and the CCD detector is extremely sensitive. As such, stray light from monitors can result in unwanted spectral peaks. The peaks can vary from monitor to monitor, but are represented as sharp (often weak) peaks that are most notable when the spectral counts from the sample in the region of one of these peaks are low. Figure 6 shows the spectral contribution from two different monitors in use on our system. The easiest way to eliminate such peaks entirely is to turn off the monitor during data collection or purchase a privacy screen for the monitor.

Carbon black. Carbon black is a black pigment composed of amorphous carbon, which is used in virtually any application requiring true black (*e.g.*, toner, tires, polyolefin fibers). Carbon black has a recognizable spectrum that consists of two broad peaks (see the carbon tape spectrum in Figure 2). While these peaks can be quantitatively interpreted under proper conditions, the carbon black feature is qualitatively unmistakable when present.

Analysis of various pigments, including several white, titanium dioxide pigments, showed a contribution of carbon black in the Raman spectrum. Carbon black, even at an extremely low (<< 1%) concentration, can cause a material to darken, and you would certainly not expect carbon black to be present in a white pigment. Therefore, it appears that carbon black is present as a contaminant. The reason for the contamination is not clear; however, even a fresh pigment sample can show carbon black peaks. One possible explanation is that amorphous carbon is being deposited during analysis as a result of localized sample heating.

Although detectable, the presence of carbon black in pigment spectra has about as much significance during interpretation as carbon in the EDS spectrum of a quartz grain mounted on a carbon stub. Thus, while it would be interesting to study this feature further, other than noting its presence, it does not pose any issues to the identification of the actual pigments in a sample. If it is suspected that carbon black detected by Raman spectroscopy is present as a minor component (such as in gray paint), light microscopy can be used to verify the actual presence of carbon black in a paint sample.

Polarization. Polarization is not an artifact, but can manifest itself as a notable effect in Raman spectra. While polarization is an optical property that forensic scientists most commonly associate with polarized light microscopy, the same principles apply to Raman spectroscopy, where laser light is inherently polarized. The effects of polarization in Raman spectroscopy manifest themselves most notably (for the forensic scientist) as changes in peak intensity or the complete disappearance of a peak. An example of this can be seen in the collection of a Raman spectrum from the mineral zircon, where the 1010 Δcm^{-1} peak can be at a relative intensity of anywhere from 0 to 100% of the strongest peak in the spectrum depending on the orientation of the sample relative to the laser and collection optics. While this can be used advantageously in certain studies, more often than not, it is an issue for those interested simply in phase identification. Fortunately, most organic pigments are randomly oriented and small enough that the Raman analytical volume contains multiple pigment particles. As such, the orientation is not an issue. Effect pigments, which are often intentionally dispersed in a preferred orientation, may be more susceptible to these effects.

Stitching. In CCD-based dispersive spectrometers, a spectrum is collected by focusing the collected scattered photons onto a grating, which in turn, is projected onto a CCD chip. Only a portion of the entire spectrum can be focused onto the CCD chip at a time (based on the dispersion of the grating and the width of the CCD). As such, instrument designers have come up with various ways to scan a larger range of the spectrum than can fit on the CCD at any one time. One of these methods involves collecting discrete images of adjacent regions of the spectrum, which are then stitched together based on a predefined overlap algorithm. Due to differences in the efficiency of the grating as a function of wavelength, stitching algorithms may not accurately capture data in the

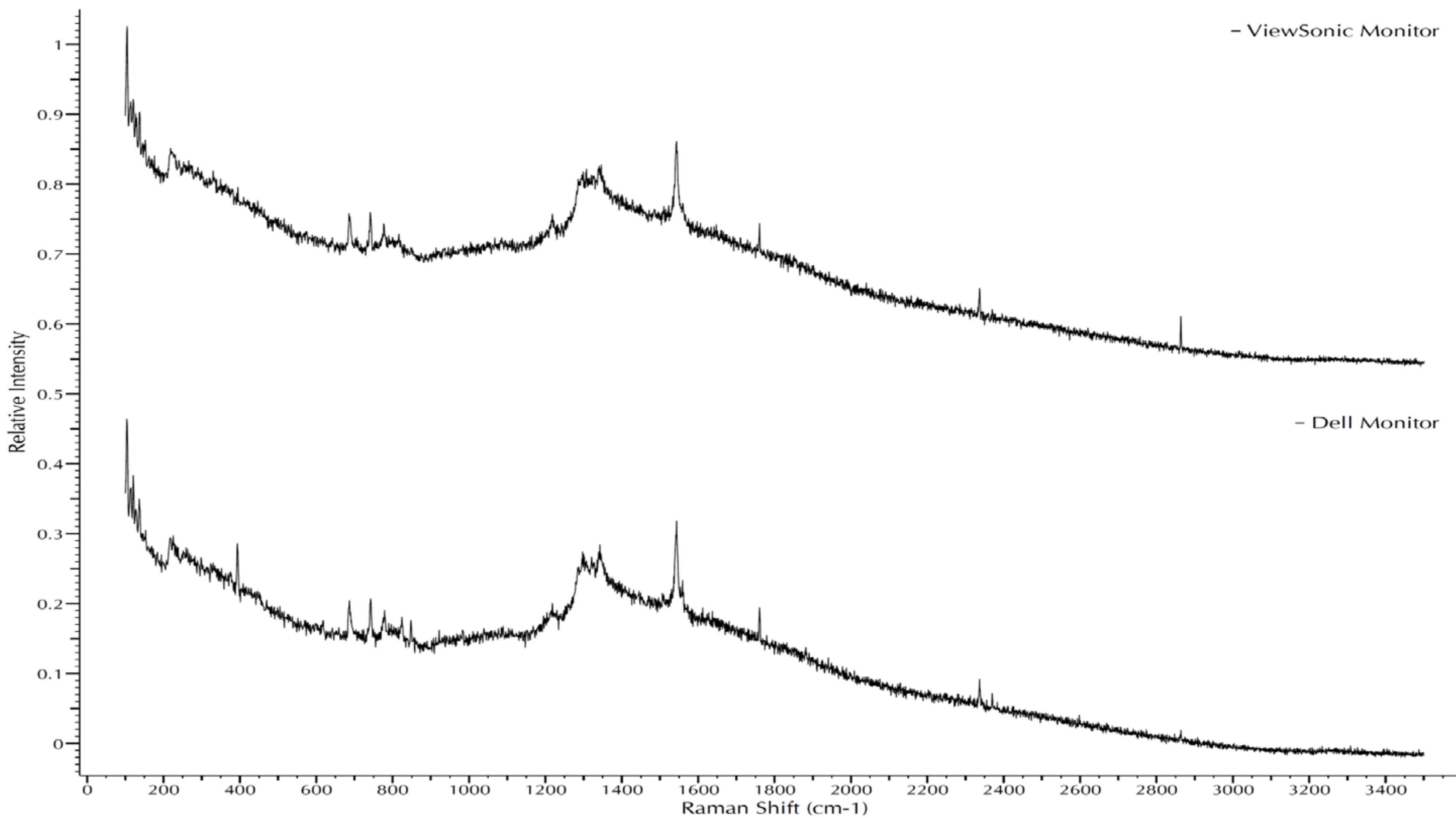


Figure 6. Raman spectra from two different computer monitors, illustrating the locations fof peaks that can be contributed by a monitor near the objective. Raman spectra shown here were collected by focusing the laser onto a polished aluminum slide.

overlapping regions between two “frames.” The author has used some spectrometers where peaks falling on these edges can change position or width. When attempting to collect data, it is generally a good idea to make sure that the final spectrum is collected in a way such that critical peaks do not fall on stitch boundaries.

LIBRARY OF RAMAN REFERNCE SPECTRA

The reference spectra collected are presented in Appendix B. Each reference spectrum is listed on an individual page, with major and moderate peak positions labeled. The specific spectral acquisition details (laser, power, bleaching, etc.) are also included on each page.

VERIFICATION OF PIGMENT IDENTITY

Confidence in sample provenance is of paramount importance to any materials relied upon as a reference material. One of the most significant examples we have encountered involved the identification of a yellow pigment in a case (Beckert, 2009). In our initial examination by Raman spectroscopy, the pigment matched a spectrum from a pigment library we had downloaded from an online academic resource. Based on this spectral match, the yellow material was tentatively identified as Indian Yellow (the name listed on the reference spectrum). Indian Yellow is unusual in that it is a historical pigment that was purportedly produced from the urine of cows fed on an exclusive diet of mango leaves (a theory which has never been authenticated). True Indian Yellow has been characterized as a salt (magnesium or calcium) of euxanthic acid. Further examination of the unknown pigment by EDS showed that the pigment contained virtually no magnesium or calcium. The FTIR spectrum of this yellow material was then collected and identified as tartrazine (FD&C Yellow #5). A Raman spectrum collected from a physical sample of tartrazine from our own reference collection showed that indeed, the unknown yellow material was tartrazine, as was the reference spectrum that we had downloaded. It turns out that tartrazine is one of several compounds that has been used as a modern substitute for Indian Yellow; however, tartrazine is not true Indian Yellow. The results of the examination demonstrate both the importance of a systematic naming scheme and the importance of verified reference materials.

Attempts were made to obtain pigment reference samples of the highest quality; however, as discussed earlier in this manual, there is no formal, orderly process by which to acquire pigments. As such, we have maintained the best possible record of provenance for all pigments acquired. This record is the basis of the Quality Index ranking developed for this database. Of course, the Quality Index ranking is only a ranking of provenance; it is not a verification of pigment identity. As part of this research, we have attempted, through several independent means, to verify the authenticity of the pigment reference samples presented in this research. The approaches included:

- Analysis of the multiple samples acquired by different sources or produced by different manufacturers (when multiple samples of a given pigment are available)
- Analysis of pigments by EDS to check for consistency with the published chemical formula
- Consistency checking of spectra during pigment classification
- Analysis of pigments by pXRD, FTIR, and PLM

Each of these topics is discussed in more detail in the following sections.

ANALYSIS OF MULTIPLE SAMPLES FROM DIFFERENT SOURCES

In many instances, our reference collection contains multiple samples of the same pigment. In such cases, these samples generally represent different manufacturers or different lots. While it was not feasible to collect and interpret reference spectra from every pigment in our collection, in several instances, multiple samples of the same pigment were analyzed. In some cases, this was done as a spot check to look for consistency of reference samples. For example, we had samples of PY 154 produced by 4 different manufacturers. Examination of these spectra, shown in Figure 7 illustrates the pigments are qualitatively indistinguishable. It is also interesting to note that these four pigments represent Quality Index scores ranging from 1 to 5.

ANALYSIS OF PIGMENTS BY EDS

All pigments published in this manual were analyzed by EDS for the purpose of comparing the elements qualitatively detected with the elements listed in the chemical formula of the pigment. While this is, admittedly, not a rigorous identification of the compound, it is another independent consistency check to verify the pigment label. Most of the pigments agreed completely with the published chemical composition. Several interesting points arose during this elemental consistency check:

Confirmation of unusual elements. When compounds contain a relatively unusual element, EDS is good way to check for this compound (both in reference materials and in samples). Figure 8 illustrates EDS spectra verifying the elemental composition of a few such compounds (PY 154 (fluorine), PY 161 (niobium), PY 53 (antimony), and PY 184 (bismuth, vanadium)).

More specific identification. Pigment numbers containing colons are often received from manufacturers or suppliers without the colon information. Colons, as discussed in the nomenclature section, denote changes in a metal salt or sometimes polymorph differences. PB 15, which is produced in three different polymorphs (*i.e.*, α, β, γ), can be distinguished by subtle differences in the Raman spectrum or by pXRD. Barium Lithol Red can be produced with three different cations: PR 49, a sodium salt; PR 49:1, a barium salt; and PR 49:2, a calcium salt. One example of these pigments contains barium, sodium and calcium by EDS (Figure 9a). This data suggests that this pigment is actually a mixture of three different organic salts. Examination of the Raman spectrum of this pigment, in Figure 9b, shows that it is distinguishable from the only other lithol red pigment in our collection (PR 49:2), which was confirmed as calcium salt by EDS. The ambiguity in this data suggests the sample labeled PR 49 is actually a mixture of several salts (PR 49, PR 49:1 and PR 49:2); it was not included as a spectral reference sample in this study, which is intended to represent pure pigment samples.

The previous example is another illustration of the confusion that can arise as a result of Colour Index nomenclature. In this case, PR 49 is thought of as PR 49:0. The label PR 49 (without a colon number) officially denotes the sodium salt of this pigment. It does not (as might be expected) denote a general (or undefined) example of the pigment.

Mislabeled Pigments. While this was not found to be the case very often, occasionally misidentified pigments were uncovered by examining the EDS data. One example was a pigment supplied to us by a distributor (Q.I. 4) as PY 35 (CdZnS). Elemental analysis (and later comparison to other Raman spectra) showed that the sample actually

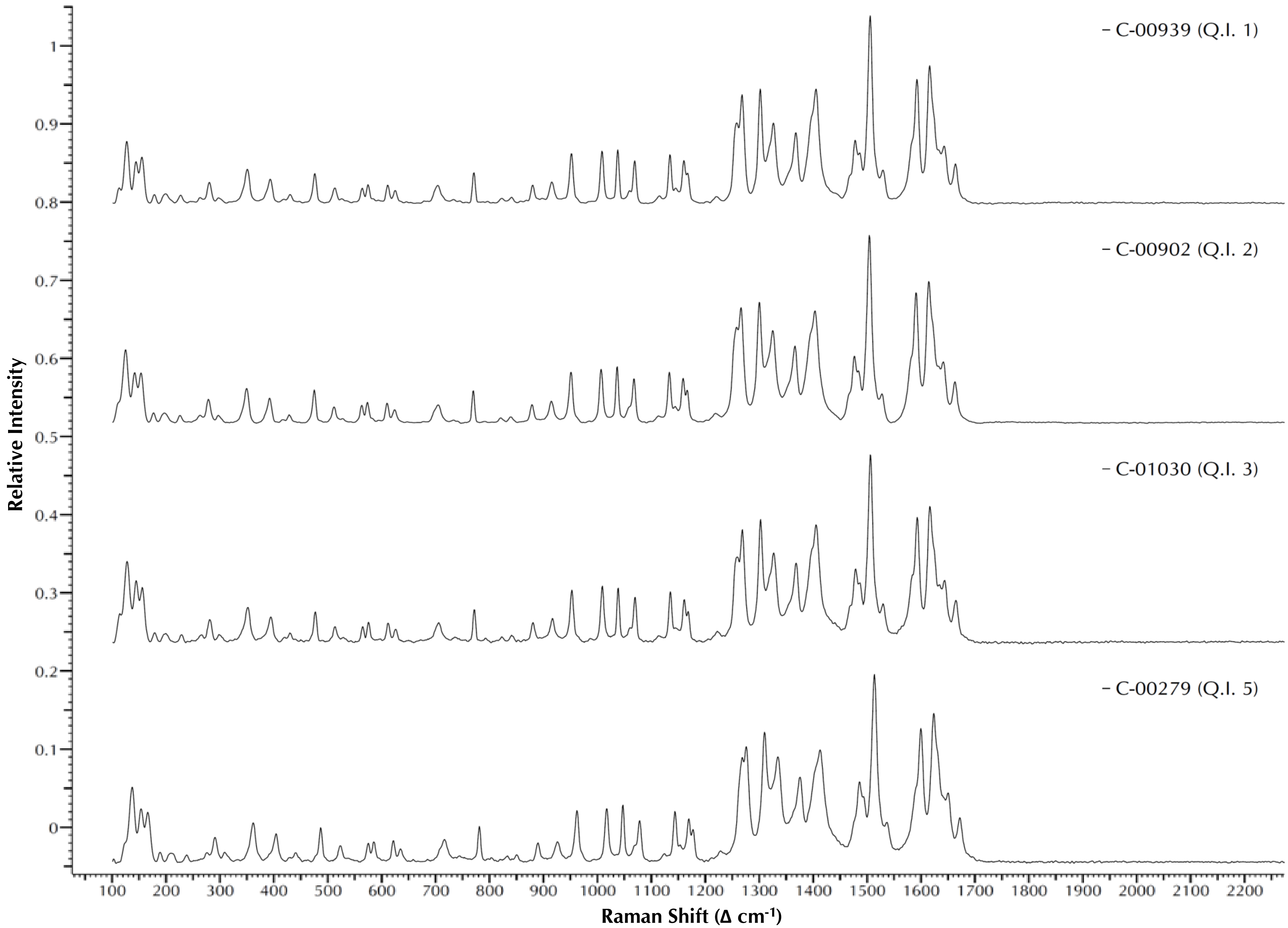


Figure 7. Raman spectra of four PY 154 samples each produced by a different manufacturer. The Quality Index (Q.I.) score for each reference sample is listed on the Figure as well.

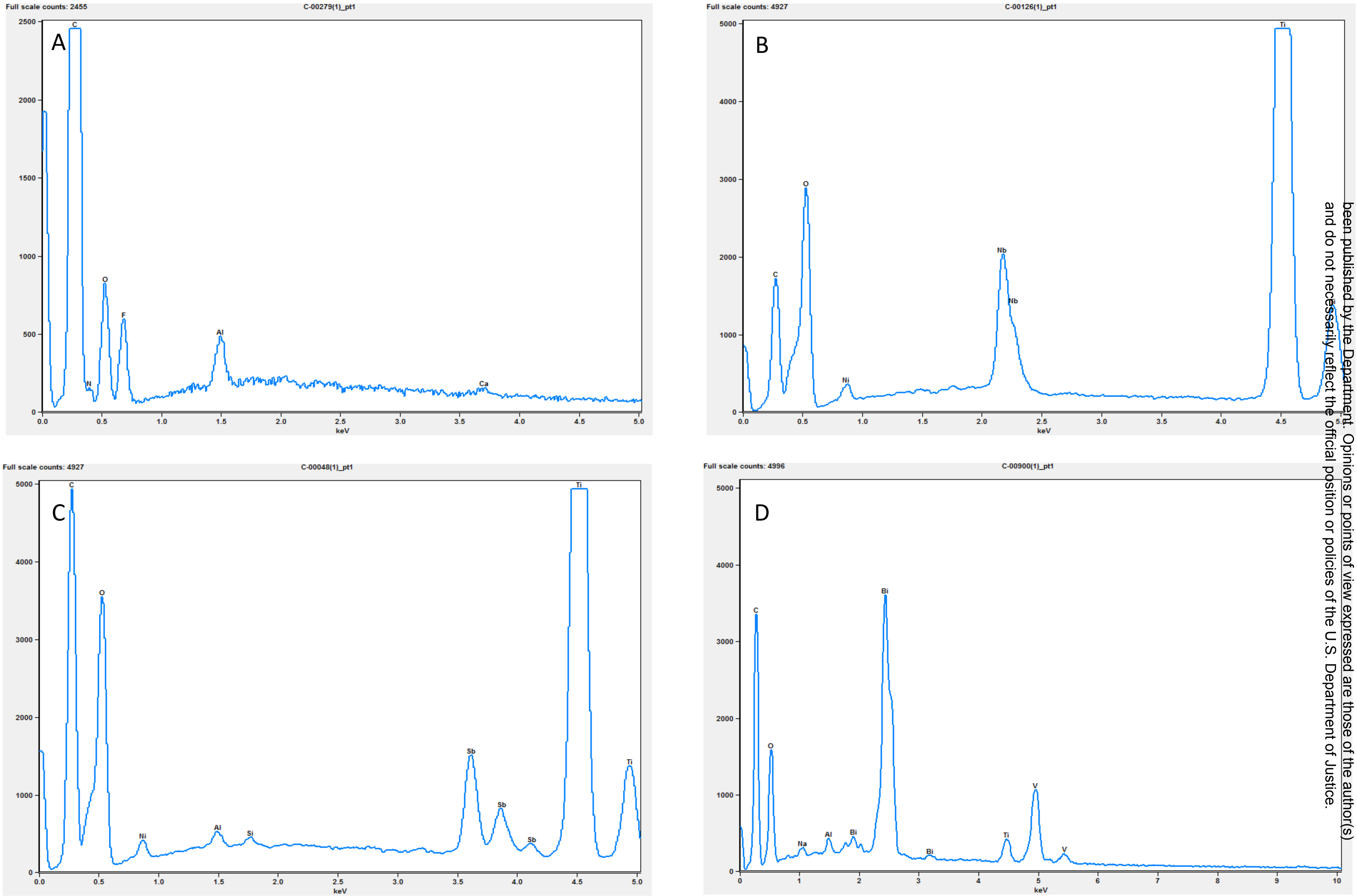


Figure 8. Verificiation of pigment identity by EDS. A) PY 154, which contains fluorine; B) PY 161, which contains niobium; C) PY 53, which contains antimony; D) PY 184, which contains bismuth and vanadium.

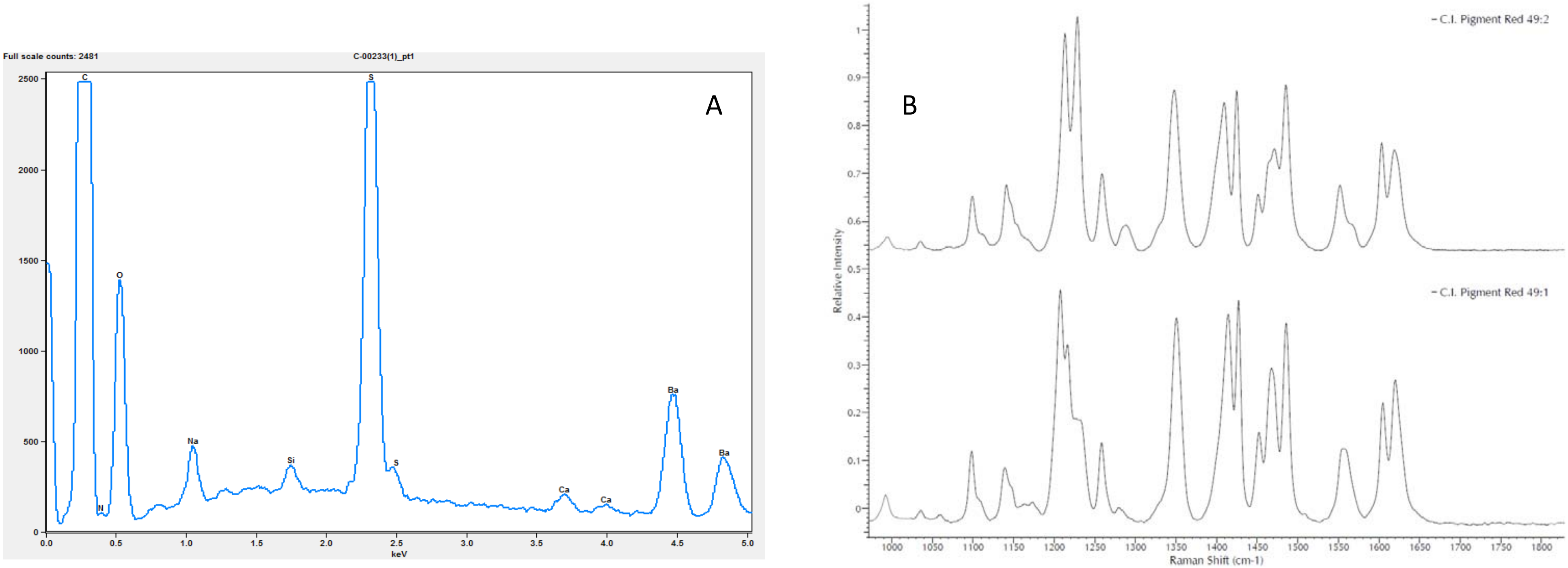


Figure 9. A) EDS spectrum of a pigment labeled PR 49, which actually contains components of PR 49:1 and PR 49:2 as well. B) Area of Raman spectrum comparing the mixed PR 49 sample (lower) and PR 49:2 (upper).

contains cadmium, sulfur, barium and selenium (Figure 10). Examination of the Colour Index suggests that this pigment is actually PO 20:1 or PR 108:1. This brings up another ambiguity in the Colour Index. PO 20 and PR 108 share a common constitution number 77202:1. C.I. Constitution Number 77202:1 represents a $CdSeS_x$ with barium sulfate. Again, because this pigment sample has not been specifically identified, it has not been included in the spectral reference library.

Compositional Variation. As mentioned in the nomenclature section, C.I. generic names do not always denote a single, specific composition. One example of this can be seen by examining the elemental analysis of a series of PG 7 samples which vary in their shade of green. The elemental analyses of four PG 7 samples normalized to copper are shown in Figure 11a. Note that the bromine and chlorine compositions vary among these four samples. Examination of the Raman spectra (Figure 11b), show only subtle variations in one of the spectra, which is the sample that contains appreciably more bromine.

Additives and Fillers. One might expect that pigments are pure compounds. In practice, pigments supplied by manufacturers often contain various additives, which can be added to improve dispersion, flow, or achieve a specific tint. While the characterization of these additives is not directly relevant to this work, it is of relevance to ensure that any contribution of these additives to the reference spectrum is noted. During the course of the EDS data interpretation, several likely inorganic additives were identified, which include barium sulfate ($BaSO_4$), halite (NaCl), an aluminosilicate, and possibly silica (Figure 12).

CONSISTENCY CHECKING DURING PIGMENT CLASSIFICATION

While classifying pigments, it was found (as would be expected) that pigments with similar chemistries share spectral similarities. This characteristic allowed us an additional means to verify that pigments had the expected chemistry. In a few cases, pigments were identified that did not belong. In both cases, the pigments had been mislabeled by the distributor from whom they were obtained.

ANALYSIS OF PIGMENTS BY pXRD AND FTIR

In some instances, pigments were also examined by other analytical techniques to clarify particular questions. For example, PV 23 exists in two polymorphs (α and β). These polymorphs have different Raman spectra, but are often supplied only as PV 23. pXRD was utilized to clarify this point. A literature reference to the powder diffraction pattern of both polymorphs was found, which gave the peak positions for both and also indicated that the alpha polymorph produced a weak diffraction pattern (Quillen, 2010). Analysis of the diffraction patterns of various samples permitted identification of the beta form; however, the alpha form could be only tentatively identified (based on the weak diffraction pattern).

FTIR spectroscopy was utilized to check consistency between samples when additional examples of a given pigment were available; however, despite a large reference library of reference spectra, very few pigment records were available.

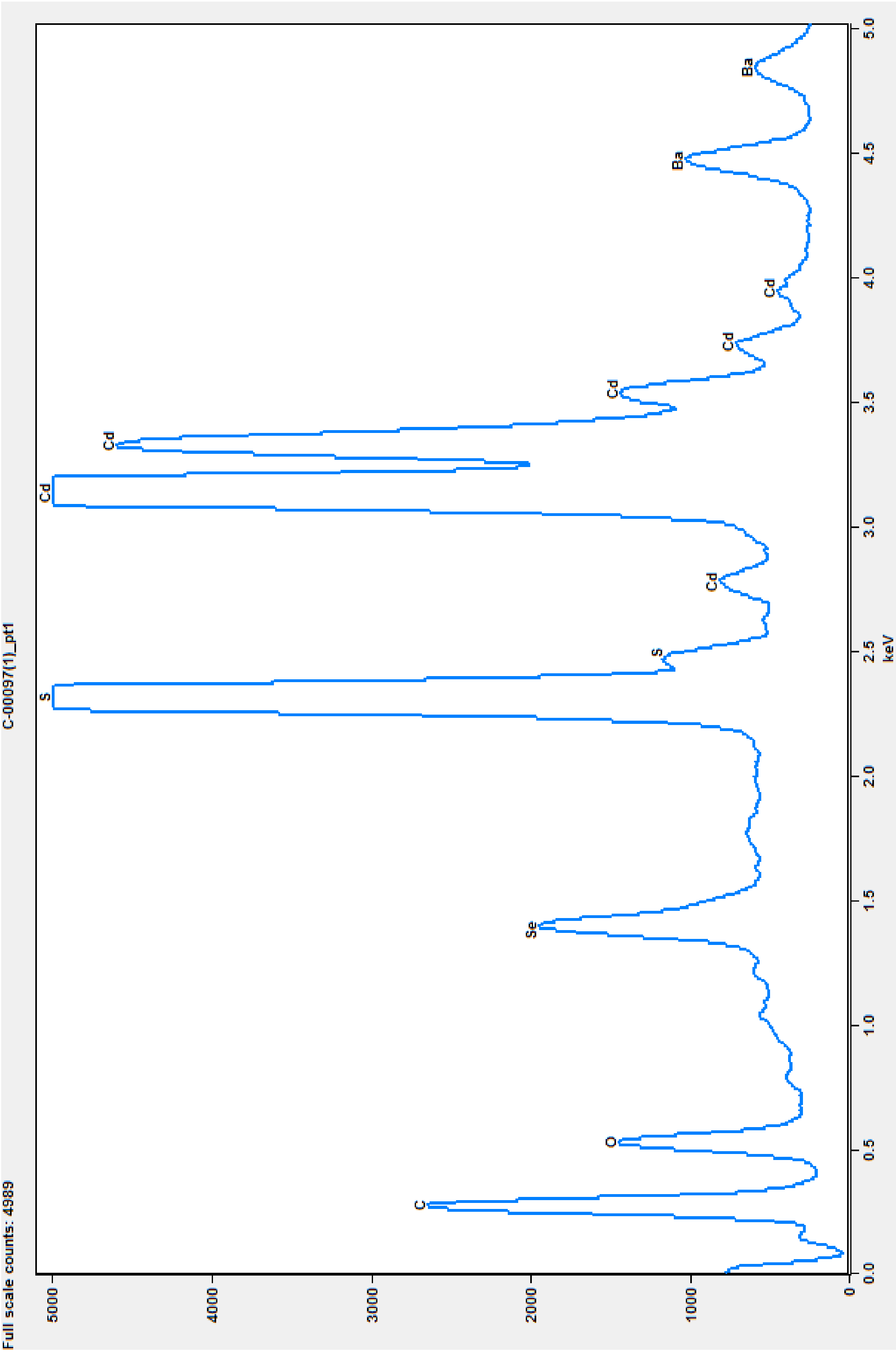


Figure 10. Elemental analysis of a sample mislabeled as PY 35.

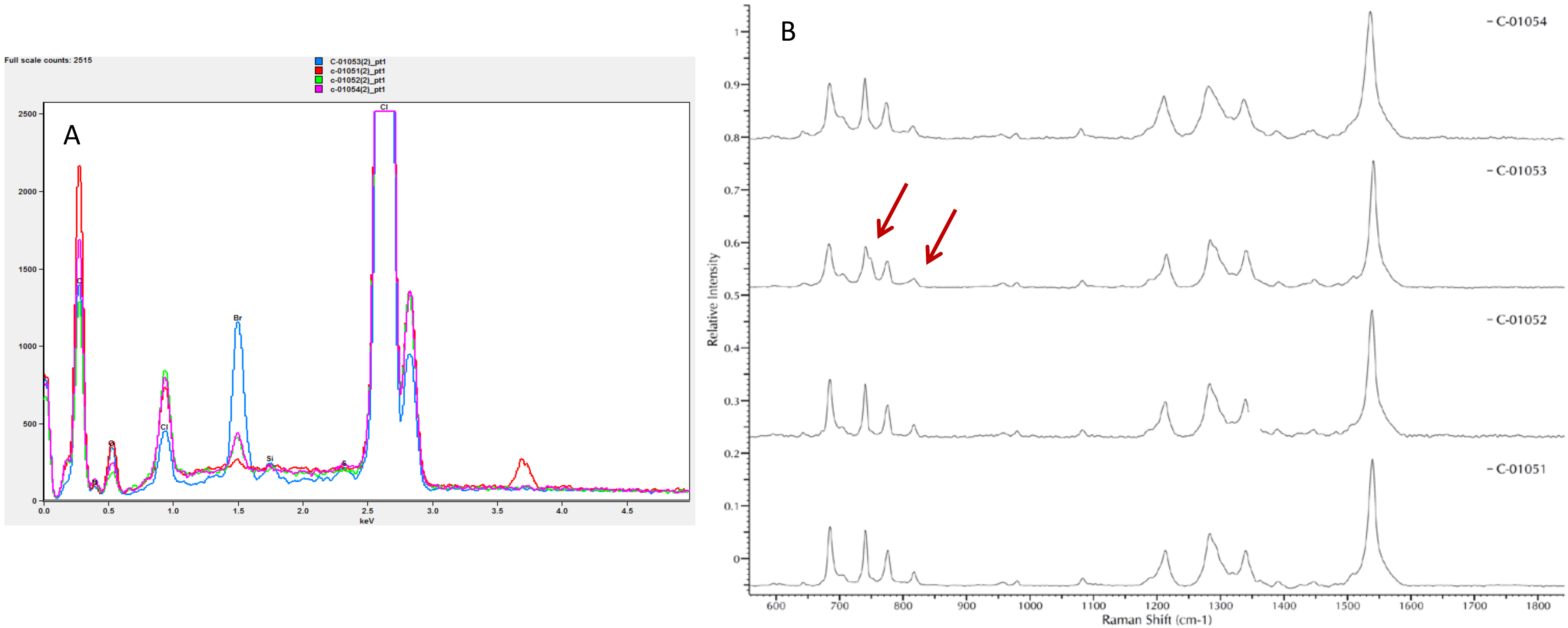


Figure 11. Comparison of A) elemental data and B) Raman spectra of four visibly different PG 7 samples. Arrows denote areas of difference.

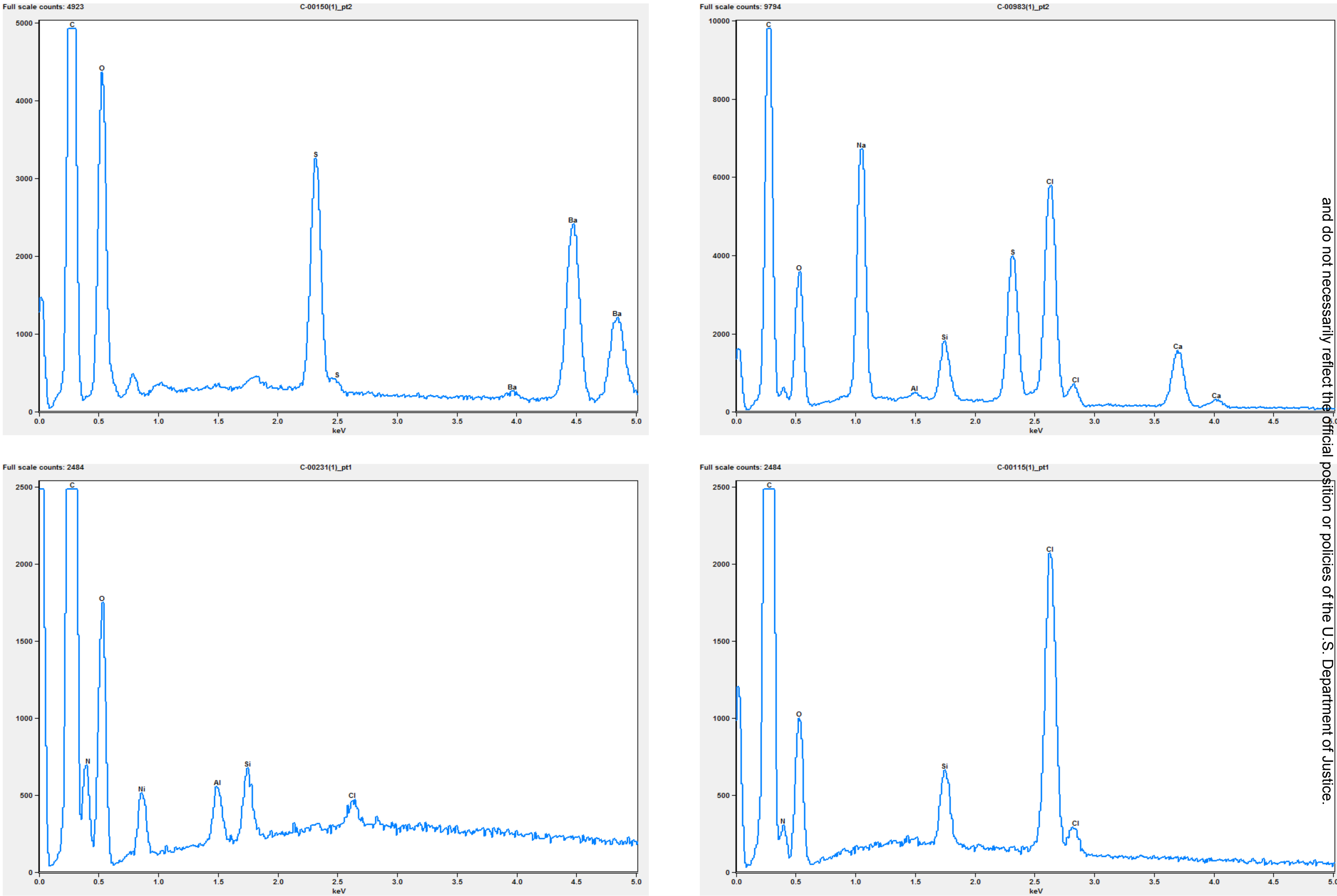


Figure 12. Elemental data suggesting the presence of fillers in the sample. Indications of A) barium sulfate; B) sodium chloride; C) an aluinosilicate, D) silica.

DEVELOPMENT OF IDENTIFICATION SCHEME

The previously presented research was conducted in support of the main goal of this project: the development of a pigment classification scheme. The resulting scheme developed through this research, is presented in Appendix D. The ultimate purpose of this scheme is to provide a way to identify one or more pigments within a sample. A no less important goal is to be able to gain an understanding of the extent to which a given pigment can be identified. As an analogy, consider the subject of animal hair identification. Depending on the sample, it may be possible to take the identification to the species level; however, in other cases, the sample can only be identified to the genus level. In the case of pigment identification, it is often possible to specifically identify a pigment (*e.g.*, PR 112), but in others cases, the Raman spectra of closely related pigments cannot be differentiated (*e.g.*, the diarylide group). In the second case, another analytical method (*e.g.*, EDS, FTIR, or PLM) may help to further specify the identification; however, in some cases it will never be possible to fully identify a pigment by techniques suitable to forensic science. Even in that case, the identification can at least be taken to the group level.

The classification scheme is presented in Appendix D and consists of a flowchart based on the strongest peaks of reference pigments. Strongest peaks are utilized because initial data has suggested that often, only the strongest Raman bands are detectable once a pigment is embedded in a matrix. At the terminus of each branch of the flowchart are pages that contain spectral overlap plots from each group. This permits direct comparison of spectra from within a given chemical group. For a higher resolution spectrum of a given pigment, users can refer to Appendix B.

The classification scheme that has been developed can be used in two ways. The flowchart can be followed by checking for the presence of various strong peaks. Using successively weaker peaks, one can work down the scheme as far as is possible with a given sample spectrum. In the other case, an identified pigment can be compared against other pigments within a given chemical group to determine whether it can be distinguished from other similar pigments. Since often only the strongest peaks are detected in a casework sample, this scheme permits a user to determine the extent to which a pigment can be specifically identified.

PIGMENT CLASSIFICATION APPROACHES

The topic of pigment classification starts out simply enough, but becomes fairly complex in the details. The Colour Index groups colorants by “chemical” groups such as indioid, indolphenol, oxazine, etc. These groups are useful; however, they do not represent all colorant chemistries and group assignments are often debatable.

As such, it was necessary to develop our own approach to classification. It should be said from the start that while the end product is unique, many of the fundamental groupings were guided by several factors, including contacts in the pigment industry, reference books (*e.g.*, Buxbaum and Pfaff, 2005; Herbst and Hunger, 2004; Smith, 2002), and the Raman spectra themselves. The full list of classification categories that was developed for this work is presented in Appendix C.

At a basic level, pigments can be grouped into two categories without much debate: organic and inorganic. It turns out that with the exception of a few pigments, organic and inorganic pigments can be separated by general location of the major peak in the sample. If the 100% peak is greater than Δ1100 cm^{-1}, then the peak belongs to an organic pigment; if less than Δ1100 cm^{-1}, the peak belongs to an inorganic pigment. The sub-categorization of organic and inorganic pigments is discussed in the following two sections.

ORGANIC PIGMENTS

In working through the Raman data for the purpose of classifying the organic pigments, we quickly came to the realization that the Colour Index classification categories were either too broad or did not correspond with the groupings that developed based on spectral similarities. Literature reviews, discussion with industry sources, and most importantly, our own studies into the chemistry of these colorant molecules, led us to the development of new classification categories, which are presented in Appendix C.

The organic categories and sub-categories developed ultimately represent spectral similarities and differences. While it is likely that these can be translated to functional group or structural similarities, that is beyond the more pragmatic goals of the research being conducted at this time. In attempting to understand the reasons for these groupings, we have prepared, in Appendix D, a series of stacked spectra, which are intended to highlight the similarities and differences that are used to make delineations in the flowchart.

When attempting to utilize the flowchart, one should generally start with the strongest peak. This will often lead to a proper classification. In some cases, the "similar" peaks among spectra of a given chemical group were not associated with the 100% peak but rather the 2nd, 3rd, or 4th strongest peak. Those who remember or have some familiarity with using the XRD Hanawalt method for examination of diffraction patterns will find this approach somewhat familiar. When finally arriving at a terminus of the flowchart (which contains comparative Raman spectra), the fully labeled Raman reference spectrum (which can be found in Appendix B) should be examined to confirm the identification. As a rule of thumb, the peaks in Raman spectroscopy might vary in relative intensity to a small extent; however, the absolute peak positions should generally be within about 3 or 4 cm^{-1} (for a relatively sharp peak).

INORGANIC PIGMENTS

The classification of inorganic pigments is not as straightforward as one might expect. Various published compendiums of pigments treat inorganic pigments in different ways. Some utilize the cation, while others group by anion, and others utilize color. Mineralogists rely on crystal structure for classification. In the end, we decided to group the inorganic pigments by anion and found that this scheme permits relatively straightforward classification.

As a general rule, the strongest Raman band for inorganic pigments fell below Δ1100 cm^{-1}. There are a few exceptions, as can be seen when examining the flowchart; however, the majority of pigments follow this "rule."

FLUORESCING PIGMENTS

Although this is not strictly a group, like organic or inorganic, fluorescing pigments do represent a collection of pigments worthy of discussion. The pigments listed here, in Table 6, represent pigments whose fluorescence is great enough that no peaks could be identified. The pigments in this table are organized by color, where the red pigments represent the largest group. The spectra are included in Appendix B for completeness. The pigments in this group are also listed on the terminal pages of each chemical group in the flowchart to assist with pigment differentiation. Some of the fluorescence spectra have interesting shapes that might be of some analytical value (given the same instrument and collection conditions).

Table 6. A summary of fluorescing pigments.

MT Ascension	C.I. Generic Name	C.I. Constitution Number	MT Ascension	C.I. Generic Name	C.I. Constitution Number
C-00954	C.I. Pigment Black 26	77494	C-00678	C.I. Pigment Orange 20	77202
C-00952	C.I. Pigment Black 32	71133			
C-00553	C.I. Pigment Black 8	77268	C-00582	C.I. Pigment Red 108	77202
			C-00835	C.I. Pigment Red 108:1	77202:1
C-00852	C.I. Pigment Blue 1	42595:2	C-00829	C.I. Pigment Red 168	59300
C-00974	C.I. Pigment Blue 1:2	42595:3	C-00105	C.I. Pigment Red 173	45170:3
C-00593	C.I. Pigment Blue 31	77437	C-00909	C.I. Pigment Red 177	65300
C-00252	C.I. Pigment Blue 61	42765:1	C-00856	C.I. Pigment Red 179	71130
C-00970	C.I. Pigment Blue 78	42090:2	C-00830	C.I. Pigment Red 190	71140
			C-00404	C.I. Pigment Red 83	56000
C-00053	C.I. Pigment Brown 24	77310	C-00174	C.I. Pigment Red 83:1	58000:1
C-00159	C.I. Pigment Brown 6	77491			
			C-00936	C.I. Pigment Violet 19	73900
C-00483	C.I. Pigment Green 14	77199	C-00880	C.I. Pigment Violet 29	71129
C-00818	C.I. Pigment Green 18	77289			
C-00101	C.I. Pigment Green 4	42000:2	C-00113	C.I. Pigment Yellow 119	77496
			C-00138	C.I. Pigment Yellow 147	60645
			C-00380	C.I. Pigment Yellow 162	77896

IN SITU IDENTIFICATION

The first and main goal of this work was to conduct a systematic identification and characterization of reference pigment samples. The data and validation methods described above have established the basis necessary to begin to judge the practical effectiveness and utility of pigment identification by Raman spectroscopy as a forensic tool. Further systematic research is required to answer these application questions definitively, and this topic is the subject of a continuation proposal submitted to NIJ. However, we present here a survey of some encouraging results that illustrate the potential benefits of Raman microspectroscopy to *in situ* pigment identification as a practical method in the forensic sciences.

SAMPLE PREPARATION AND ANALYSIS

For a basic analysis or screening, the only requirement is that the laser be focused on the color layer of the sample. Ideally, colored layers should be exposed directly to the laser. Paint samples with a clearcoat can be analyzed directly; however, it is preferable to either remove part of the clearcoat (to expose the color layer) or cut a cross section (preferred) to permit analysis of each underlying colored layer. If utilizing a macro system, it may be necessary to analyze a planar sample as opposed to a cross section.

Sample substrates are discussed earlier in this guide. We have found polished aluminum slides to work extremely well; however, for thick samples, the substrate is of little significance.

While a microscope based Raman system will provide better spatial resolution, a macro system, or even a handheld system, can be utilized to obtain at least some information about pigment content. However, it is important to note, having used everything from handheld instruments, to analytical benchtop systems, to high resolution research systems, not all systems are equal. Selection of an instrument will have an impact on both the quality and ease of data collection. The parameters described in the Collection Methods section of this manual provide insight into some instrumental features that were utilized or adjusted to obtain the reference spectra presented in this manual. These parameters are also generally applicable to the analysis of paint samples and may assist with selecting a suitable Raman system. This manual does not make any attempts to rate or evaluate the pros and cons of various instrument features; we present parameters only as guidelines that were used for this research.

With a confocal microscope system, it should be possible to analyze discrete pigments or pigment clumps (which are on the order of 5 µm or less). In practice, this can be difficult and further research has been proposed to optimize this approach to the focused identification of select pigments.

SPECTRAL INTERPRETATION

Raman (and infrared) spectra of mixtures are more difficult to interpret than spectra of pure compounds. In infrared spectroscopy, careful sample preparation can allow for examination of physically purified components. In the study of pigments, this is not generally possible, due to the minute size of individual pigment particles. Therefore, a systematic approach to spectral interpretation is important. A variety of automated search algorithms on various commercial software programs have been utilized by the authors. While it is sometimes possible to successfully identify pigment spectra in this way, it becomes more difficult when two or more pigments are present. The pigment classification and identification scheme that has been developed serves to provide a simple method for identifying strong peaks in the spectrum being examined. Once the first compound is identified, the process can be repeated on the remaining strong peaks. In this way, no computer search is necessary.

Whenever possible, attempts should be made to account for all peaks present in a spectrum. While the binder is often not observed, it can contribute to the spectrum. Fillers should also be considered when attempting to evaluate spectra.

When comparing questioned and known spectra, it is important to remember that paint is heterogeneous. We have found that analyses from a random area of the paint chip are often, but not always representative of the paint. One of the application examples presented below illustrates this point. Effect pigments can also complicate this statement, particularly when attempting to analyze pigments in such a paint with a macro-Raman system.

After conducting a spectral interpretation, it is important to always consider if the identification(s) actually make sense, given the macroscopic color of the sample (and its surrounding layers). For instance, the identification of

PG 7 as a component of a gray paint might not make intuitive sense. While it turns out that this pigment is commonly found in gray paints, the presence of a green pigment can be verified by PLM.

The use of supplemental methods for identification and confirmation is always preferable; however, Raman spectroscopy does provide a standalone means by which to identify pigments in a sample.

APPLICATION EXAMPLES

The main purpose of this research has been to establish the foundation for exploiting pigment evidence in coatings by Raman spectroscopy through the development of a spectral reference library and identification scheme. To illustrate the potential value of this information, we present a few examples of how this identification scheme might be used. A systematic study of a much larger number of paint samples will be required to explore the evidentiary significance of such paint pigment, which is the subject of a submitted grant continuation proposal.

The automotive and architectural paints studied were analyzed with little to no sample preparation. The goal of this limited sample preparation was to illustrate the level of pigment information that could be obtained in the shortest period of time. Note that color layers were analyzed directly, by removing or avoiding any clear coat that was present. These thick samples (*i.e.,* too thick for transmitted light) were visually examined by reflected light, which effectively eliminated any potential benefit that confocal microscopy might provide in allowing analysis of specific single particles. Again, this was done to minimize sample preparation. Several areas on each sample were analyzed to ensure that the collected spectrum was representative of the general paint. It is likely additional information could be gained by studying these color layers as smears or thin sections. Again, we have proposed to explore this further in the proposed continuation of this project.

APPLICATION 1: AUTOMOTIVE PAINT SAMPLES

The automotive paints were selected from our collection of paint samples. A total of five automotive paints were examined. The peaks in each Raman spectrum were identified using the identification scheme. A summary of the pigments and our approach to the identification of pigments in each sample is presented below.

Red Paint. The Raman spectrum of this paint is shown in Figure 13. The sample contains both PO 43 (perinone) and PR 209 (quinacridone). A small peak at 1050 Δcm^{-1} suggests the presence of barium sulfate, which is confirmed by EDS analysis.

Red Paint. The Raman spectrum of this paint is shown in Figure 14. Using the flowchart, PR 209 (quinacridone) is initially identified. Of the remaining peaks, a second pigment, PO 36 was identified (benzamidizolone). Finally, of the remaining minor peaks, a yellow iron oxide pigment was identified.

Red Paint. The spectrum collected from this paint is shown in Figure 15 and is an example of a fluorescing red paint. The single major peak in the spectrum suggests the presence of PO 21 (chromate); however, the minor peak is not strong enough to confirm this identification alone. However, in an investigative analysis (rather than comparative) this information could be of assistance.

Blue Paint. The Raman spectrum of this paint is shown in Figure 16. The peaks in this spectrum are all consistent with the spectrum of copper phthalocyanine. More specifically, this paint was identified as PB 15:1 or PB 15:2.

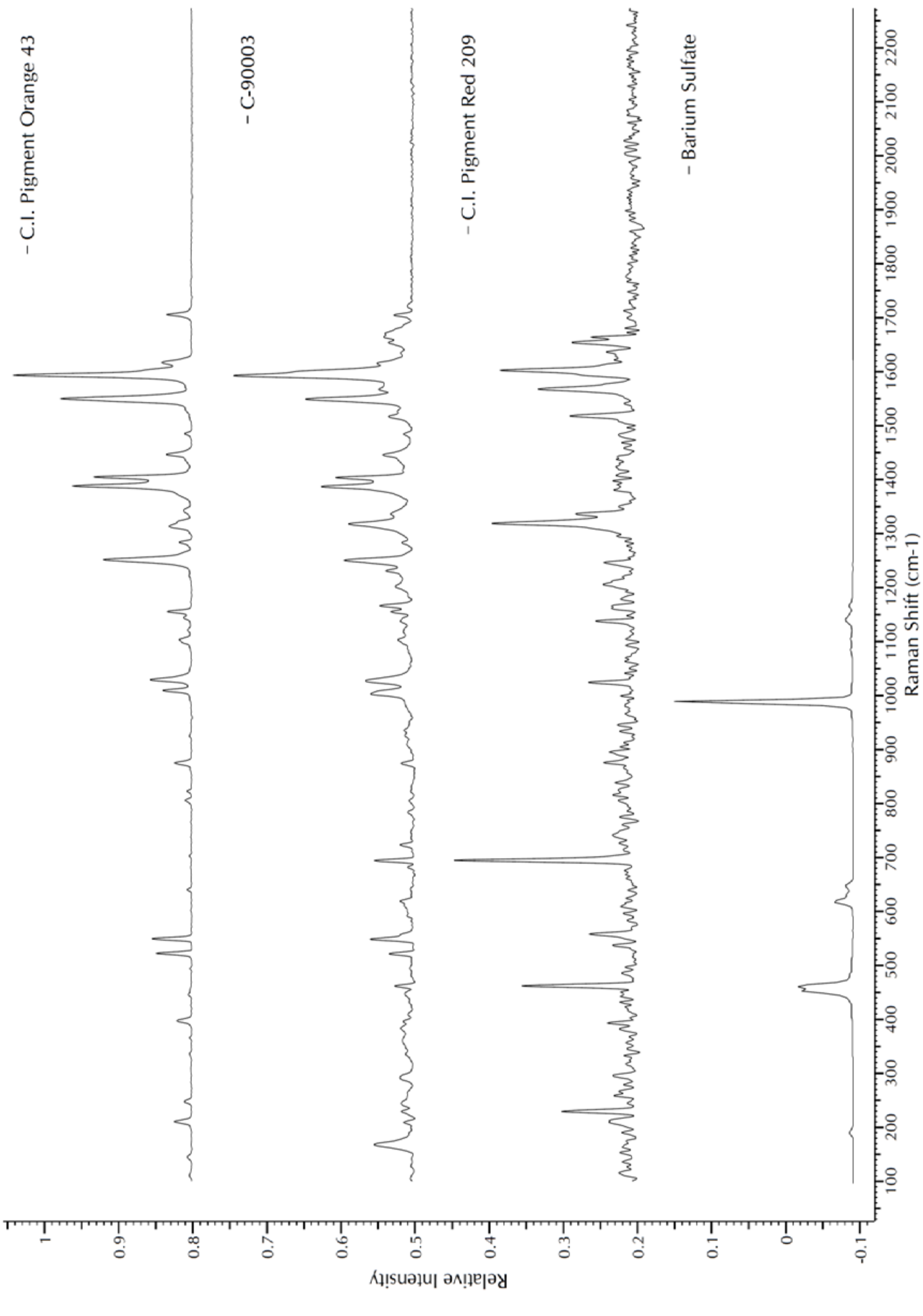


Figure 13. Raman spectrum of an unknown red automotive paint compared to reference spectra of PO 43 and PR 209. Barium sulfate was also identified in the spectrum.

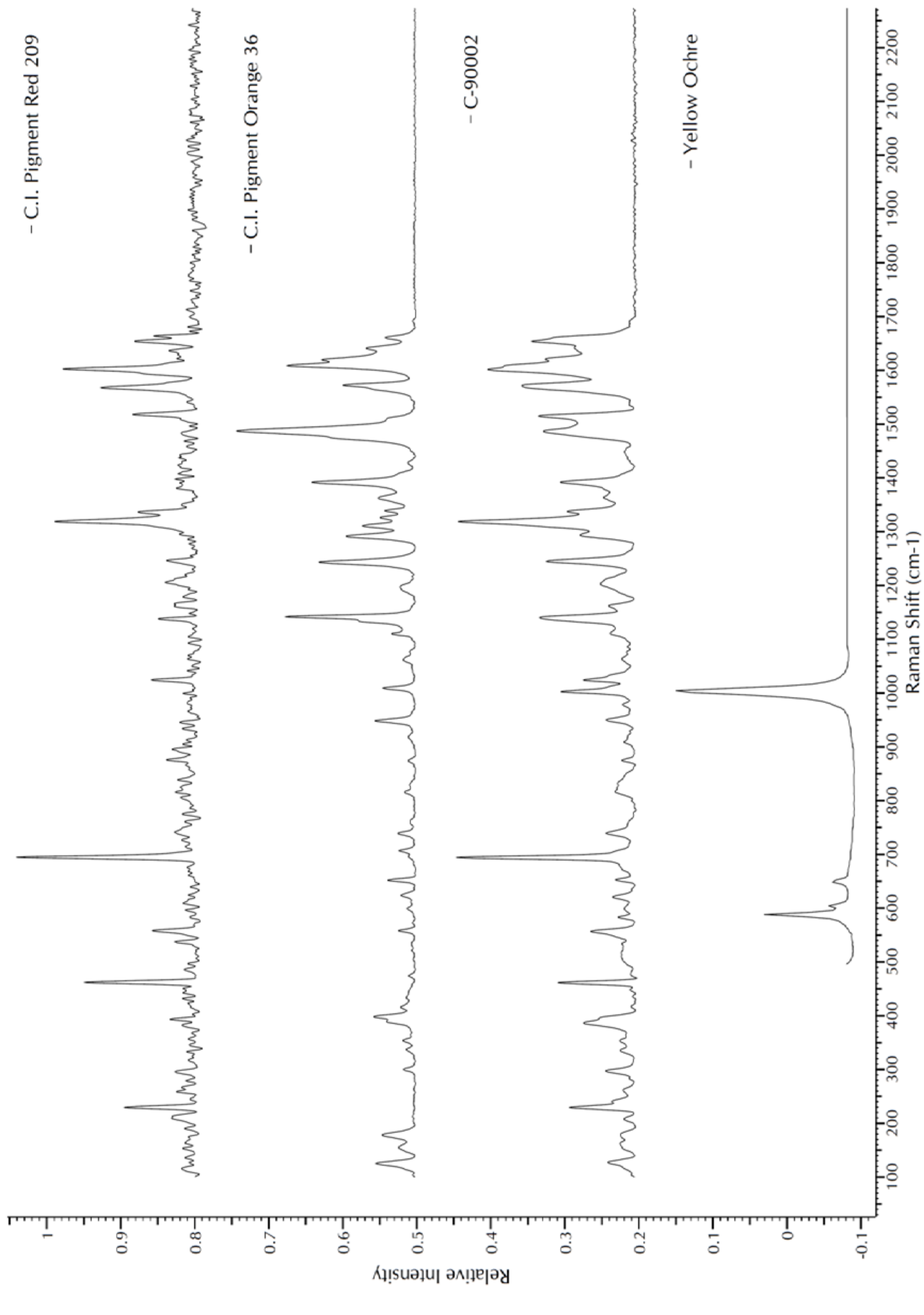


Figure 14. Raman spectrum of another unknown red automotive paint compared to reference spectra of PO 36, PR 209 and an iron oxide pigment.

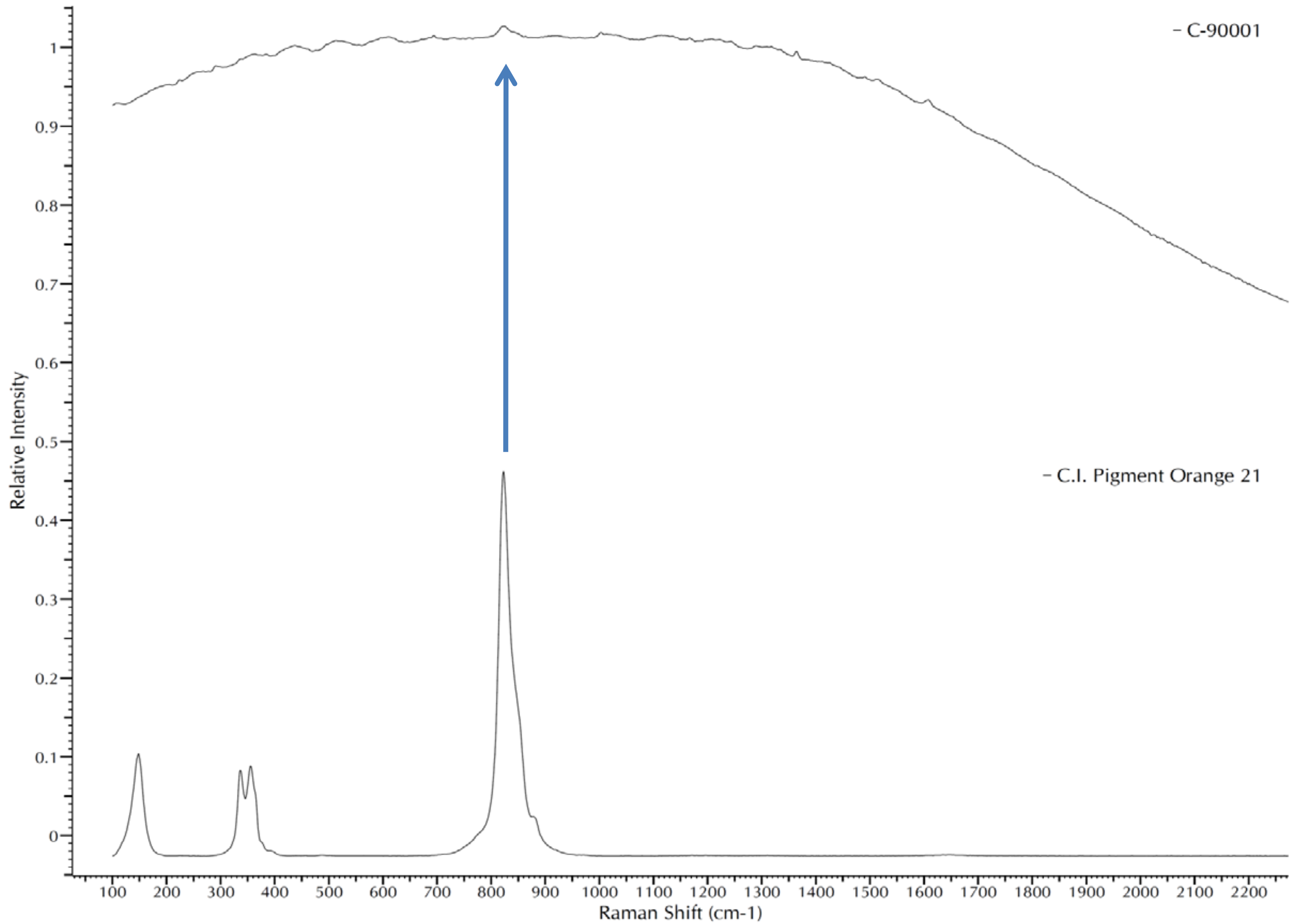


Figure 15. Raman spectrum of a fluorescing unknown red automotive paint compared to a reference spectrum of PO 21.

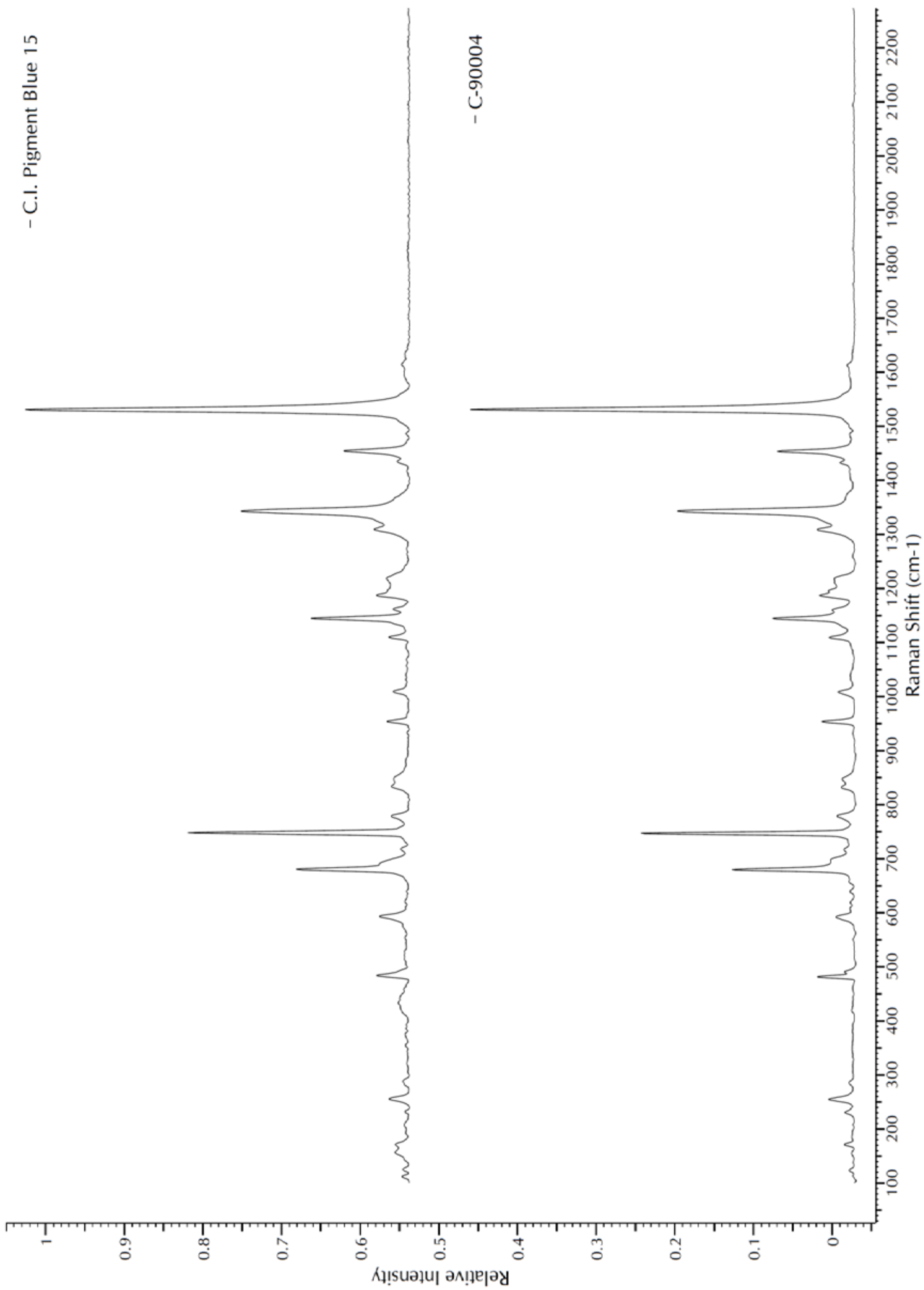


Figure 16. Raman spectrum of an unknown blue automotive paint compared to reference spectra of PB 15:1.

These two colon numbers cannot be differentiated by Raman spectroscopy, as they both contain the same polymorph (alpha).

Yellow Paint. The Raman spectrum of this paint is shown in Figure 17. Two pigments were identified, PY 6 (rutile) and PY 154 (benzimidazolone). A minor peak at $\Delta 1050\ cm^{-1}$ suggests the presence of barium sulfate, which is confirmed by EDS analysis.

APPLICATION 2: ANALYSIS OF ARCHITECTURAL PAINTS

The analysis of architectural paints is typically of less interest to most criminal investigations since this type of paint evidence does not occur as often; however, this paint can be analyzed and interpreted in a fashion similar to that of automotive paint.

Green Spray Paint. The Raman spectrum collected from this paint is shown in Figure 18. Interpretation of the paint utilizing the scheme identifies three pigments: PB15:1/2 (phthalocyanine), a yellow diarylide pigment, and PB 27 (cyanide). The yellow diarylide pigment can only be identified to a chemical class and not to an individual pigment. In the case of diarylides, the 11 pigments in that class cannot be further subdivided based on the spectrum obtained from this sample. Therefore, it is possible to state that the diarylide pigment in this sample is one of the following: PY 12, PY 83, PY 188, PY 17, PY 81, PY 152, PY 13, PY 14, PY 55, PY 170, or PY 174. This illustrates the importance of having a strong reference collection. In the event that only a small reference collection of pigments was available, and PY 14 was found to be a spectral "hit" based on an automated search, one might be tempted to identify the yellow colorant as this specific pigment, when indeed, this is only one of several possibilities.

Comparison of two green paints. These paints have a similar hue. The paints can be differentiated by FTIR spectroscopy. Examination of the Raman spectrum shows that both samples contain PG 7 and PW 6 (rutile) as the major colorants (Figure 19a and b). In one sample, however, certain areas of the spectrum show both anatase and calcite (Figure 19b). Based on the presence of a second TiO_2 polymorph and calcite, these paints can be differentiated.

While proponents of FTIR would be justified in stating that FTIR was able to provide this same information, it is important to note that Raman spectroscopy provides not only discrimination, but a potentially faster and even less consumptive method (in addition to the benefit of actual pigment identification).

CONCLUSIONS

This manual was written for the purpose of providing forensic science laboratories with the fundamental research, spectral database, classification scheme and basic guidelines for the examination of paint pigments in forensic evidence. There is still much work to be done, some of which is proposed as a continuation to the present grant. Nonetheless, this work has included, among other items, the following:

- Development of the most thorough spectral pigment database that currently exists in the world.
- Supporting analyses to check that the analyzed pigments were consistent with their labels.
- Development of an objective Quality Index for ranking the provenance of a pigment sample.

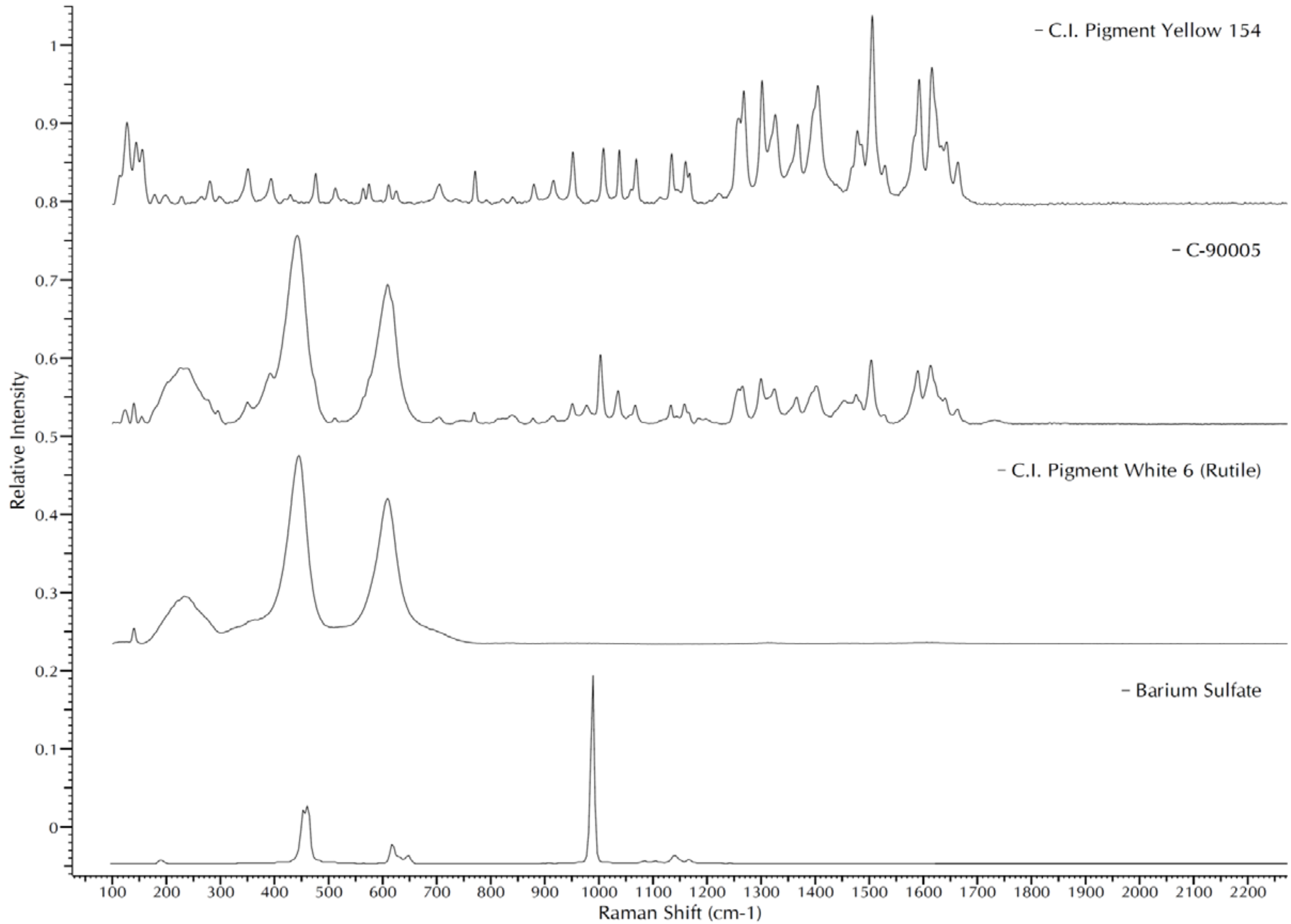


Figure 17. Raman spectrum of an unknown yellow automotive paint compared to reference spectra of PY 154, rutile, and barium sulfate.

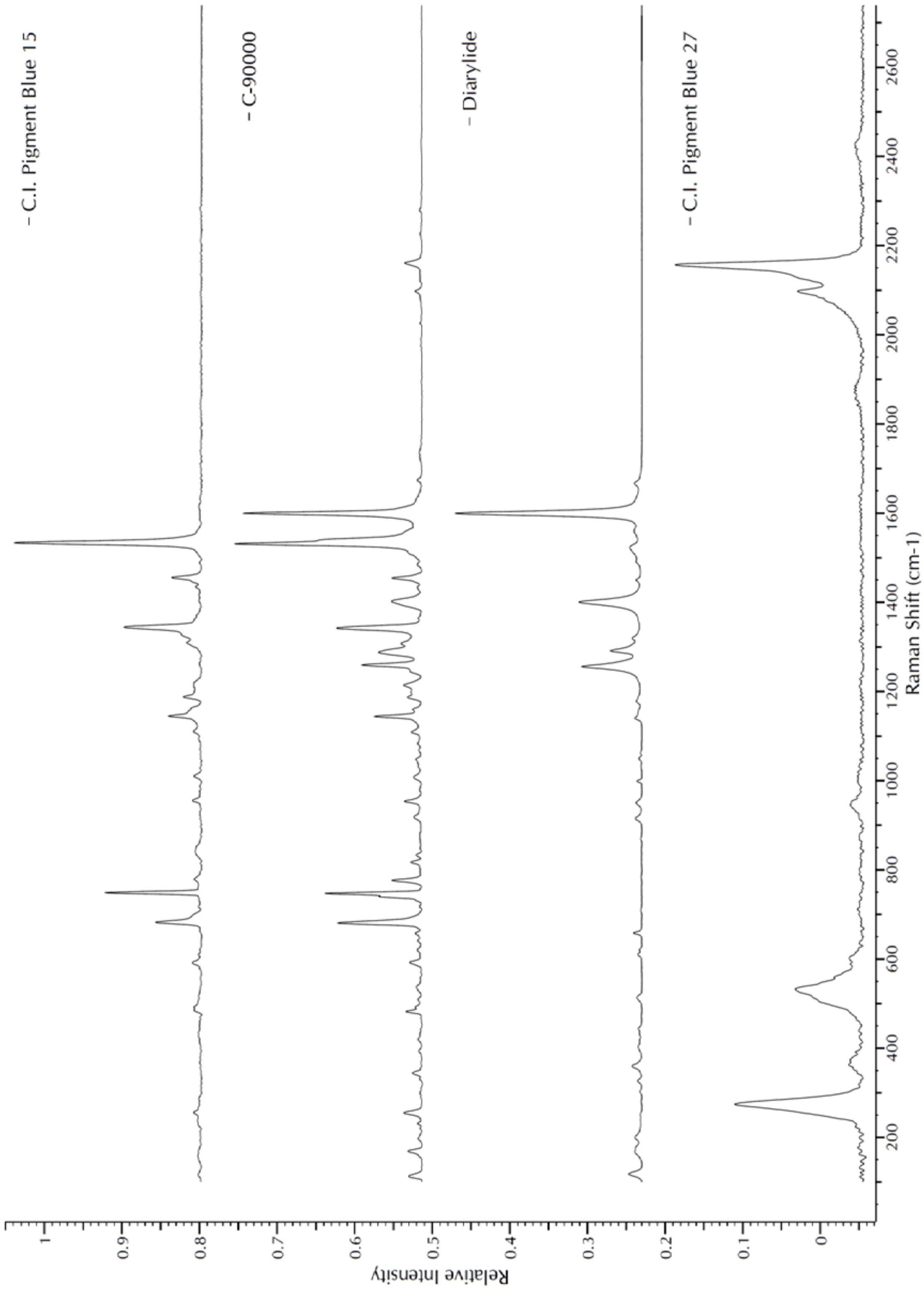


Figure 18. Raman spectrum of a green spray paint compared to reference spectra of identified pigments.

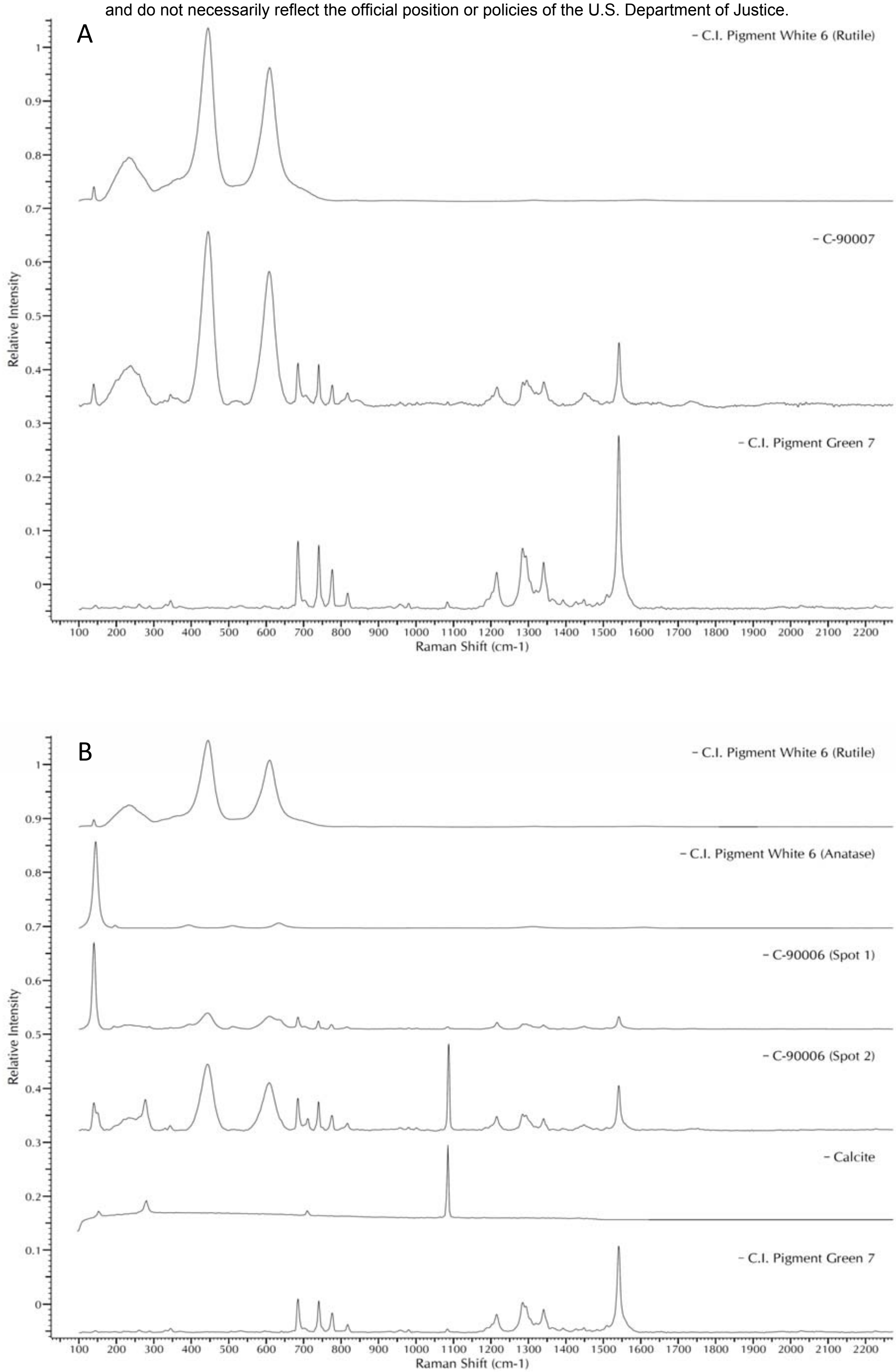


Figure 19. A) Green paint containing PG 7 and rutile compared to another green paint B) containing PG 7, rutile, anatase, and calcite.

- Development of a pigment classification scheme to permit interpretation of pigment evidence.
- Development of this “Manual” for forensic practitioners as a guide to encourage the development and use of Raman spectroscopy as an analytical method in forensic laboratories.

This research is not in any way intended to replace FTIR or SEM/EDS as analytical methods for paint examination. Instead, this research is intended to open up new avenues for exploiting a major and variable component of paint samples: pigments. As discussed in this manual, this information holds potential value in both comparative and investigative examinations.

REFERENCES AND BIBLIOGRAPHY

Bales, H., and C. Palenik. "Planar Section of Multilayer Paint Chips." Inter/Micro. IL, Chicago. 2008.

Beckert, J. " Indian Yellow: Historical Pigment and Modern Confusion." Inter/Micro. IL, Chicago. 2009.

Bell, S., L. Fido, S. Speers, and W. Armstrong. "Rapid Forensic Analysis and Identification of "Lilac" Architectural Finishes Using Raman Spectroscopy." *Applied Spectroscopy* 59.1 (2005): 100-08. Print.

Black, Crayton K. "Vat Dyes as Pigments." *Industrial and Engineering Chemistry* 32.10 (1940): 1304-306. Print.

Buckle, J. L., D. A. MacDougall, and R. R. Grant. "PDQ - Paint Data Queries: The History and Technology Behind the Development of the Royal Canadian Mounted Police Forensic Science Laboratory Services Automotive Paint Database." *Canadian Society of Forensic Science* 30.4 (1997): 199-212. Print.

Buxbaum, Gunter, and Gerhard Pfaff. *Industrial Inorganic Pigments*. Weinheim: Wiley-VCH, 2005. Print.

Buzzini, P., and G. Massonnet. "A Market Study of Green Spray Paints by Fourier Transform Infrared (FTIR) and Raman Spectroscopy." *Science & Justice* 44.3 (2004): 123-31. Print.

Buzzini, P., G. Massonnet, and F. M. Sermier. "The Micro Raman Analysis of Paint Evidence in Criminalistics: Case Studies." *Journal of Raman Spectroscopy* 37 (2006): 922-31. Print.

Castle, D. "Pigment Analysis in the Forensic Examination of Paints. II. Analysis of Motor Vehicle Paint Pigments by Chemical Tests." *Journal of the Forensic Science Society* 22.2 (1982): 179-86. Print.

Chang, Hua, and Pei Jane Huang. "Thermo-Raman Studies on Anatase and Rutile." *Journal of Raman Spectroscopy* 29.2 (1998): 97-102. Web.

Color Pigments Manufacturers Association, Inc. *CPMA Classification and Chemical Descriptions of the Complex Inorganic Color Pigments*. 4th ed. Alexandria: Color Pigments Manufacturers Association, 2010. Print.

"Colour Index Generic Names, Constitution Numbers and the Use of Colon Numbers." *Home*. Society of Dyers and Colourists, July 2007. Web. <http://www.sdc.org.uk/>.

Colour Index. 2nd ed. Bradford: Society of Dyers and Colourists, 1971. Print.

Colour Index. 3rd ed. Bradford: Society of Dyers and Colourists, 1982. Print.

Corset, Jacques, and George Turrell. *Raman Microscopy: Developments and Applications*. Amsterdam: Academic, 1996. Print.

Cousins, D. R. "The Use of Microspectrophotometry for the Identification of Pigments in Small Paint Samples." *Forensic Science International* 24.3 (1984): 183-96. Print.

Cousins, D. R. "The Use of Microspectrophotometry in the Examination of Paints." *Forensic Science Review* 1.2 (1989): 141-62. Print.

Crown, David A. *The Forensic Examination of Paints and Pigments*. Springfield: Thomas, 1968. Print.

Curry, C., D. Rendle, and A. Rogers. "Pigment Analysis in the Forensic Examination of Paints. I. Pigment Analysis by X-ray Powder Diffraction." *Journal of the Forensic Science Society* 22.2 (1982): 173-77. Print.

De Gelder, Joke, Peter Vandenabeele, Filip Govaert, and Luc Moens. "Forensic Analysis of Automotive Paints by Raman Spectroscopy." *Journal of Raman Spectroscopy* 36.11 (2005): 1059-067. Print.

Derrick, Michele R., Dusan Stulik, and James M. Landry. *Infrared Microspectroscopy in Conservation Science*. Los Angeles: Getty Conservation Institute, 1999. Print.

Downs, R. T. *The RRUFF Project: an Integrated Study of the Chemistry, Crystallography, Raman and Infrared Spectroscopy of Minerals*. 2006. Web. <http://rruff.info/>.

Eastaugh, Nicholas. *The Pigment Compendium: a Dictionary of Historical Pigments*. Amsterdam: Elsevier, 2004. Print.

Eastaugh, Nicholas. *The Pigment Compendium: Optical Microscopy of Historical Pigments*. Amsterdam: Elsevier, 2004. Print.

Edwards, Howell G.M., Nik F. Nik Hassan, and Paul S. Middleton. "Anatase - a Pigment in Ancient Artwork or a Modern Usurper?" *Analytical and Bioanalyitical Chemistry* 384 (2006): 1356-365. Print.

Feller, R. "Terminology and Procedures Used in the Systematic Examination of Pigment Particles with the Polarizing Microscope." *Artists' Pigments: A Handbook of Their History and Characteristics*. Ed. M. Bayard. Vol. 1. Cambridge: Cambridge UP, 1986. 285-98. Print.

Feller, Robert L. *Artists' Pigments: a Handbook of Their History and Characteristics*. Vol. 1. Washington: National Gallery of Art, 1986. Print.

FitzHugh, Elisabeth West. *Artists' Pigments: a Handbook of Their History and Characteristics.* Vol. 3. Washington: National Gallery of Art, 1997. Print.

Gettens, Rutherford J., and George L. Stout. *Painting Materials: a Short Encyclopaedia*. New York: Dover Publications, 1966. Print.

Govaert, F., and M. Bernard. "Discriminating Red Spray Paints by Optical Microscopy, Fourier Transform Infrared Spectroscopy and X-ray Fluorescence." *Forensic Science International* 140.1 (2004): 61-70. Print.

Hamer, P. "Pigment Analysis in the Forensic Examination of Paints. III. A Guide to Motor Vehicle Paint Examination by Transmitted Light Microscopy." *Journal of the Forensic Science Society* 22.2 (1982): 187-92. Print.

Harkins, T., J. Harris, and O. Shreve. "Identification of Pigments in Paint Products by Infrared Spectrophotometry." *Analytical Chemistry* 31.4 (1959): 541-45. Print.

Herb, J., and C. Palenik. "Use of Surface Enhanced Raman Spectroscopy (SERS) Applied to the Study of Fluorescing Pigments and Dyes." American Academy of Forensic Sciences National Meeting. IL, Chicago. 2011.

Herbst, Willy, Klaus Hunger, and Gerhard Wilker. *Industrial Organic Pigments: Production, Properties, Applications*. Weinheim: Wiley-VCH, 2004. Print.

Hudson, G., R. Andahl, and S. Butcher. "The Paint Index—the Colour Classification and Use of a Collection of Paint Samples Taken from Scenes of Crime." *Journal of the Forensic Science Society* 17.1 (1977): 27-32. Print.

Jochem, G., and R. Lehnert. "On the Potential of Raman Microscopy for the Forensic Analysis of Coloured Textile Fibres." *Science & Justice* 42.4 (2002): 215-21. Print.

Kotrlý, M. "Application of X-ray Diffraction in Forensic Science." *Zeitschrift Für Kristallographie Supplements* (2006): 35-40. Print.

Kuptsov, A. H. "Applications of Fourier Transform Raman Spectroscopy in Forensic Science." *Journal of Forensic Sciences* 39.2 (1994): 305-18. Print.

Lewis, Peter A. *Organic Pigments*. Philadelphia: Federation of Societies for Coatings Technology, 1988. Print.

Lombardi, John R., Maco Leona, Tuan Vo-Dinh, and Philip Antoci. *Development of Advanced Raman Spectroscopy Methods and Databases for the Evaluation of Trace Evidence and the Examination of Questioned Documents (Phase I)*. Rep. no. 2006-DN-BX-K034. Print.

Massonet, G., and W. Stoecklein. "Identification of Organic Pigments in Coatings: Application to Red Automotive Topcoats. Part III: Raman Spectroscopy (NIR FT-Raman)." *Science & Justice* 39.3 (1999): 181-87. Print.

Mazzella, W., and P. Buzzini. "Raman Spectroscopy of Blue Gel Pen Inks." *Forensic Science International* 152.2-3 (2005): 241-47. Print.

McClure, A., J. Thomson, and J. Tannahill. "The Identification of Pigments." *Journal of the Oil and Colour Chemists' Association* 51.7 (1968): 580-635. Print.

McCrone, W. C., and S. J. Palenik. "Application of Particle Study in Art and Archaeology Conservation and Authentication." *The Particle Atlas*. Ed. J. G. Delly. 2nd ed. Vol. 5. Ann Arbor: Ann Arbor Science, 1987. 1402-413. Print.

McCrone, W. C., J. G. Delly, and S. J. Palenik. "Particle Analysis in the Crime Laboratory." *The Particle Atlas*. 2nd ed. Vol. 5. Ann Arbor: Ann Arbor Science, 1979. 1379-401. Print.

McCrone, W. C. "The Micscopical Identification of Artists' Pigments." *Journal of the International Institute for Conservation* 7 (1982): 11-34. Print.

Melo, D., M. Melo, A. Martinelli, Z. Silva, J. Cunha, and A. Lima. "Synthesis and Characterization of Lanthanum- and Yttrium-doped Fe2O3 Pigments." *Cerâmica* 53.325 (2007): 79-82. Web.

Nie, Shuming, and Steven R. Emory. "Probing Single Molecules and Single Nanoparticles by Surface-Enhanced Raman Scattering." *Science* 275.5303 (1997): 1102-106. Print.

Palenik, C., and B. Nytes. "The in Situ Identification of Pigments in CMYK Printing Inks." Inter/Micro. IL, Chicago. 2007.

Palenik, C., and B. Wilke. "Raman Spectroscopy of Organic Pigments." American Academy of Forensic Sciences National Meeting. WA, Seattle. 2010.

Palenik, C., and H. Bonta. "Microanalytical Characterization of Architectural Paint Pigments." Inter/Micro. IL, Chicago. 2008.

Palenik, C., and W. Stoecklein. "Batch to Batch Differentiation of Automobile Paints." Inter/Micro. IL, Chicago. 2003.

Palenik, C., B. Nytes, J. Beckert, H. Bonta, and S. Palenik. "Raman Spectroscopy of Forensic Evidence." National Institute of Justice (NIJ) Trace Evidence Symposium. FL, Clearwater Beach. 2009.

Palenik, C. "Forensic Pigment Analysis." National Institute of Justice (NIJ) Trace Evidence Symposium. FL, Clearwater Beach. 2009. Lecture.

Palenik, C., H. Bonta, and S. Palenik. "Microanalysis of Architectural Tinting Pigments." American Academy of Forensic Sciences National Meeting. CO, Denver. 2009.

Palenik, C., L. Nasdala, and R. Ewing. "Radiation Damage in a Zircon." *American Mineralogist* 88 (2003): 770-81. Print.

Palenik, C., S. Palenik, and B. Nytes. "An Introduction to the in Situ Identification of Pigments in Automobile and Architectural Paints by Raman Spectroscopy." Proceedings of the American Academy of Forensic Sciences National Meeting. Washington, D.C. 2008.

Palenik, C., S. Palenik, J. Herb, J. Beckert, and B. Nytes. "Chemical Classification of Pigments by Raman Spectroscopy for Forensic Applications." National Institute of Justice (NIJ) Trace Evidence Symposium. MO, Kansis City. 2011.

Palenik, C. "Workshop on Raman Spectroscopy of Forensic Evidence." International Association of Forensic Sciences Conference Proceedings. LA, New Orleans. 2008.

Palenik, S. "Advanced Forensic Microscopy: Paint and Polymers." Lecture.

Palenik, S. "Applying Chemical Microscopy to the Coatings Industry." *Paint & Coatings Industry* 14.3 (1998): 48-56. Print.

Palenik, S. "Microchemical Methods." Lecture.

Panina, N., R. Van De Ven, P. Verwer, H. Meekes, E. Vlieg, and G. Deroover. "Polymorph Prediction of Organic Pigments." *Dyes and Pigments* 79.2 (2008): 183-92. Print.

PDQ Maintenance Team. "Paint Data Query Training." RCMP Central Forensic Laboratory, Ottawa, Ontario Canada.

Quillen Lomax, Suzanne, and Tom Learner. "A Review of the Classes, Structures, and Methods of Analysis of Synthetic Organic Pigments." *Journal of the American Institute for Conservation* 45.2 (2006): 107-25. Print.

Quillen Lomax, Suzanne. "The Application of X-ray Powder Diffraction for the Analysis of Synthetic Organic Pigments. Part 1: Dry Pigments." *Journal of Coatings Technology and Research* 7.3 (2010): 331-46. Print.

Rendle, D. "X-ray diffraction in Forensic Science." *The Rigaku Journal* 19(2) (2003) 11-22. Print.

Rodgers, P. G. "The Classification of Automobile Paint by Diamond Cell Window Infrared Spectrophotometry - Part I: Binders and Pigments." *Canadian Society of Forensic Science Journal* 9.1 (1976): 1-14. Print.

Romanian Database of Raman Spectroscopy - Home for Minerals and Pigments Raman Spectra. 2008. Web. <http://rdrs.uaic.ro/>.

Roy, Ashok. *Artists' Pigments: a Handbook of Their History and Characteristics.* Vol. 2. Oxford: Oxford UP, 1993. Print.

Ryland, S. "Forensic Paint Examinations and Comparisons." Lecture.

Ryland, S. "Infrared Microspectroscopy of Forensic Paint Evidence." *Practical Guide to Infrared Microspectroscopy*. Marcel Dekker, 1995. 287-322. Print.

Scherrer, Nadim C., Zumbuehl Stefan, Delavy Francoise, Fritsch Annette, and Kuehnen Renate. "Synthetic Organic Pigments of the 20th and 21st Century Relevant to Artist's Paints: Raman Spectra Reference Collection." *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 73.3 (2009): 505-24. Web.

Smith, Hugh MacDonald. . *High Performance Pigments*. Weinheim: Wiley-VCH, 2002. Print.

Society of Dyers and Colourists, and American Association of Textile Chemists and Colorists. *Colour Index*. 4th ed. Electronic.

Stoecklein, W., and C. Palenik. "Forensic Analysis of Automotive Paints: Evidential Value and the Batch Problem." European Paint Group. Paris, France. 1998.

Stoecklein, W. "Plate-Like Pigments in Automotive Paints: A Review." *Paint and Coatings Industry* (2002): 80-83. Print.

Stoecklein, W. "The Analysis of New Plate-Like Pigments in Automotive Coatings." *Paint and Coatings Industry* (2001): 48-65. Print.

Stone, H. "Vehicle Topcoat Colour and Manufacturer: Frequency Distribution and Evidential Significance. Part II." *Canadian Society of Forensic Science* 24 (1991): 175-85. Print.

Suzuki, E., and M. Carrabba. "In Situ Identfication and Analysis of Automotive Paint Pigments Using Line Segment Excitiation Raman Spectroscopy: I. Inorganic Topcoat Pigments." *Journal of Forensic Sciences* 46.5 (2001): 1053-069. Print.

Suzuki, E. "Infrared Spectra of U.S. Automobile Original Topcoats (1974-1989): II. Identification of Some Topcoat Inorganic Pigments Using an Extended Range (4000-220 Cm-1) Fourier Transform Spectrometer." Journal of Forensic Sciences 41.3 (1996): 393-406.

Suzuki, E., and W. Marshall. "Infrared Spectra of US Automobile Original Topcoats (1974-1989): III. In Situ Identification of Some Organic Pigments Used in Yellow, Orange, Red, and Brown Nonmetallic and Brown Metallic Finishes - Benzimidazolones." *Journal of Forensic Sciences* 42.4 (1997): 619-48. Print.

Suzuki, E., and W. Marshall. "Infrared Spectra of U.S. Automobile Original Topcoats (1974-1989): IV. Identification of Some Organic Pigments Used in Red and Brown Nonmetallic and Metallic Monocoats - Quinacridones." Journal of Forensic Sciences 43 (1998): 514-42.

Suzuki, E. "Infrared Spectra of US Automobile Original Topcoats (1974-1989): V. Identification of Organic Pigments Used in Red Nonmetallic and Brown Nonmetallic and Metallic Monocoats - DPP Red BO and Thioindigo Bordeaux." *Journal of Forensic Sciences* 44.2 (1999): 297-313. Print.

Suzuki, E. "Infrared Spectra of US Automobile Original Topcoats (1974-1989): VI. Identification and Analysis of Yellow Organic Automotive Paint Pigments - Isoindolinone Yellow 3R, Isoindoline Yellow, Anthrapyrimidine Yellow, and Miscellaneous Yellows." *Journal of Forensic Sciences* 44.6 (1999): 1151-175. Print.

Suzuki, E., and M. McDermot. "Infrared Spectra of U.S. Automobile Original Finishes. VII. Extended Range FT-IR and XRF Analyses of Inorganic Pigments In Situ-Nickel Titanate and Chrome Titanate." *Journal of Forensic Sciences* 51.3 (2006): 532-47. Print.

UCL Raman Spectroscopic Library of Natural and Synthetic Pigments. Web. <http://www.spectraonline.com/collections/uclr.asp>.

Volpe, G. "Vehicle Topcoat Colour and Manufacturer: Frequency Distribution and Evidential Significance." *Canadian Society of Forensic Science* 21 (1988): 11-18. Print.

Voskertchian, G. P. "Quantitative Analysis of Organic Pigments in Forensic Paint Examination." *Journal of Forensic Sciences* 40.5 (1995): 823-25. Print.

Wilkes, B., and C. Palenik. "Organic Pigments: Analytical Characterization and Classification by Raman Spectroscopy." Inter/Micro. IL, Chicago. 2009.

APPENDIX A – LIST OF PIGMENTS

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
Inorganic 78				
Aluminate				
C.I. Pigment Blue 28 / Inorganic - Aluminate	77346 / Cobalt Blue	1345-16-0	3	C-00853
Carbon				
C.I. Pigment Black 7 / Inorganic - Carbon	77266 / Lamp black	1333-86-4	3	C-00180
C.I. Pigment Black 8 / Inorganic - Carbon	77268 / Vine Black	1339-82-8	5	C-00553
C.I. Pigment Black 9 / Inorganic - Carbon	77267 / Bone Black	8021-99-6	4	C-00568
C.I. Pigment Black 10 / Inorganic - Carbon	77265 / Graphite	7782-42-5	4	C-00398
Carbonate				
C.I. Pigment White 1 / Inorganic - Carbonate	77597 / Lead White	37361-76-5	3	C-00795
C.I. Pigment White 16 / Inorganic - Carbonate	77625 / Lead Silicate	10099-76-0	4	C-00736
C.I. Pigment White 18 / Inorganic - Carbonate	77220 / Chalk	471-34-1	3	C-00222
Chromate				
C.I. Pigment Orange 21 / Inorganic - Chromate	77601 / Chrome Orange	1344-38-3	4	C-00464
C.I. Pigment Yellow 32 / Inorganic - Chromate	77893 / Strontium Chromate	7789-06-2	4	C-00400

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 34	77600	1344-37-2 / 7758-97-6	5	C-00808
Inorganic - Chromate	Lead Chromate			
C.I. Pigment Yellow 34:1	77603:1	7758-97-6 / 7446-14-2	5	C-00702
Inorganic - Chromate	Lead Chromate with Lead sulfate			
C.I. Pigment Yellow 36	77955	37300-23-5	4	C-00442
Inorganic - Chromate	Zinc Yellow			

Cyanide

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Blue 27	77510	12240-15-2 / 14038	5	C-00037
Inorganic - Cyanide	Prussian Blue			

Hydroxide

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Blue 30	77420	12069-69-1, 1339-83	5	C-00554
Inorganic - Hydroxide	Copper Carbonate			
C.I. Pigment Brown 6	77491	52357-70-7	3	C-00159
Inorganic - Hydroxide	Iron Oxide Hydroxide Brown			
C.I. Pigment Green 20	77408	6046-93-1	5	C-00616
Inorganic - Hydroxide	Verdigris			
C.I. Pigment Green 39	77492	1319-53-5	5	C-00621
Inorganic - Hydroxide	Copper Carbonate Hydroxide			
C.I. Pigment Violet 14	77360	10101-56-1 / 13455	4	C-00465
Inorganic - Hydroxide	Cobalt Violet			
C.I. Pigment White 26	77718	8005-37-6	1	C-00324
Inorganic - Hydroxide	Talc			

Metal

Aluminum

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Metal 1	77000	7429-90-5	4	C-00486
Inorganic - Metal - Aluminum	Aluminum			

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
Nitro				
C.I. Pigment Yellow 40 Inorganic - Nitro	77357 Aureoline	13782-01-9	3	C-00104
Oxide				
C.I. Pigment Black 11 Inorganic - Oxide	77499 Mars Black	12227-89-3	3	C-00160
C.I. Pigment Black 26 Inorganic - Oxide	77494 Manganese Ferrite Black Spinel	68168-94-7	1	C-00954
C.I. Pigment Black 30 Inorganic - Oxide	77504 Chrome Iron Nickel Black Spinel	71631-15-7	1	C-00956
C.I. Pigment Black 33 Inorganic - Oxide	77537 Iron Manganese Oxide	75864-23-2	1	C-00995
C.I. Pigment Blue 36 Inorganic - Oxide	77343 Cobalt Chromite	13-29-2; 68187-11-1	3	C-00123
C.I. Pigment Brown 7 Inorganic - Oxide	77491 Brown Iron Oxide	12713-03-0	3	C-00809
C.I. Pigment Brown 24 Inorganic - Oxide	77310 Chrome Antimony Titanium	68186-90-3	3	C-00053
C.I. Pigment Brown 31 Inorganic - Oxide	77496 Zinc Ferrite Brown	68187-51-9	5	C-00043
C.I. Pigment Brown 43 Inorganic - Oxide	77536	68186-94-7	1	C-00997
C.I. Pigment Green 17 Inorganic - Oxide	77288 Chrome Oxide Green	1308-38-9 ; 68909-79	5	C-00815
C.I. Pigment Green 18 Inorganic - Oxide	77289 Viridian	12001-99-9	3	C-00818

Analyzed Pigments by Chemical Category

Inorganic - Oxide - - -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Green 26 Inorganic - Oxide	77344 Cobalt Chromite Green	68187-49-5	1	C-00993
C.I. Pigment Red 101 Inorganic - Oxide	77015 Synthetic Iron Oxide Red	1309-37-1	3	C-00826
C.I. Pigment Red 101:1 Inorganic - Oxide	77015 Natural Iron Oxide	1309-37-1	4	C-00455
C.I. Pigment Red 102 Inorganic - Oxide	77492 Natural Iron Oxide	51274-00-1	1	C-00434
C.I. Pigment Red 105 Inorganic - Oxide	77578 Red Lead	1314-41-6	3	C-00710
C.I. Pigment White 4 Inorganic - Oxide	77947 Zinc Oxide White	1314-13-2 / 91315-44	3	C-00794
C.I. Pigment White 11 Inorganic - Oxide	77052 Antimony White	1309-64-4	5	C-00377
C.I. Pigment Yellow 41 Inorganic - Oxide	77588 Naples Yellow	8012-00-8	4	C-00647
C.I. Pigment Yellow 42 (α) Inorganic - Oxide	77492 Yellow Iron Oxide	51274-00-1	2	C-00435
C.I. Pigment Yellow 46 Inorganic - Oxide	77577 Massicot Litharge	1317-36-8	3	C-00707
C.I. Pigment Yellow 53 Inorganic - Oxide	77788 Nickel Antimony Titanium Yellow Rutile	8007-18-9	2	C-00309
C.I. Pigment Yellow 119 Inorganic - Oxide	77496 Zinc Iron Yellow	68187-51-9	3	C-00113
C.I. Pigment Yellow 162 Inorganic - Oxide	77896 Chrome Niobium Titanium Yellow	68611-42-7	5	C-00380
C.I. Pigment Yellow 164 Inorganic - Oxide	77899 Manganese Antimony Titanium Buff Rutile	68412-38-4	1	C-00991

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
Phosphate				
C.I. Pigment Violet 16 Inorganic - Phosphate	77742 Manganese Violet	10101-66-3	2	C-00889
Silicate				
C.I. Pigment Blue 31 Inorganic - Silicate	77437 Egyptian Blue		5	C-00593
C.I. Pigment White 20 Inorganic - Silicate	77019 Mica	12001-26-2	3	C-00223
C.I. Pigment White 28 Inorganic - Silicate	77230 Calcium Silicate	10101-39-0; 10101-41	2	C-00340
Stannate				
C.I. Pigment Blue 35 Inorganic - Stannate	77368 Cerulean Blue	1345-19-3 / 68187-05	3	C-00850
Sulfate				
C.I. Pigment Red 108 Inorganic - Sulfate	77202 Cadmium Red	58339-34-7	4	C-00582
C.I. Pigment Red 108:1 Inorganic - Sulfate	77202:1 Cadmium-Barium Red		2	C-00835
C.I. Pigment White 5 Inorganic - Sulfate	77115 Lithopone	1345-05-7	4	C-00733
C.I. Pigment White 21 Inorganic - Sulfate	77120 Barium Sulfate	7727-43-7	3	C-00750
C.I. Pigment White 22 Inorganic - Sulfate	77120 Barytes	7727-43-7	3	C-00212
C.I. Pigment White 25 Inorganic - Sulfate	77231 Gypsum	91315-45-6 / 10101	5	C-00557

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 35 Inorganic - Sulfate	77205 Cadmium Yellow	8048-07-5 / 12442-27	4	C-00551

Sulfide

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Blue 29 Inorganic - Sulfide	77007 Ultramarine Blue	1317-97-1 / 57455-37	3	C-00845
C.I. Pigment Green 14 Inorganic - Sulfide	77199 Viridian	1306-23-6	3	C-00483
C.I. Pigment Orange 20 Inorganic - Sulfide	77202 Cadmium Orange	12656-57-4	4	C-00678
C.I. Pigment Orange 75 Inorganic - Sulfide	77283:1 Cerium Sulfide Orange	12014-93-6	1	C-00931
C.I. Pigment Orange 78 Inorganic - Sulfide	77285:0 Cerium Sulfide Orange	12014-93-6	1	C-00932
C.I. Pigment Red 106 Inorganic - Sulfide	77766 Vermillion	1344-48-5	4	C-00485
C.I. Pigment Red 265 Inorganic - Sulfide	77283:2 Cerium Sulfide Red	12014-93-6	1	C-00933
C.I. Pigment Violet 15 Inorganic - Sulfide	77007 Ultramarine Violet	12769-96-9	1	C-00994
C.I. Pigment Yellow 37 Inorganic - Sulfide	77199 Cadmium Yellow	68859-25-6	3	C-00107
C.I. Pigment Yellow 39 Inorganic - Sulfide	77085 Orpiment	1303-33-9	5	C-00625

Titanate

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Black 12 Inorganic - Titanate	77543 Natural Iron Ore/Ilmenite	68187-02-0	1	C-00953

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Brown 40 Inorganic - Titanate	77897 Manganese Chrome Antimony Titanium Brown Rrutile	71750-83-9; 69991-68	5	C-00543
C.I. Pigment Green 50 Inorganic - Titanate	77377 Cobalt Titanate Green	68186-85-6	3	C-00125
C.I. Pigment White 6 (Rutile) Inorganic - Titanate	77891 Titanium White	13463-67-7	5	C-00031
C.I. Pigment White 6 (Anatase) Inorganic - Titanate	77891 Titanium White	13463-67-7	5	C-00032
C.I. Pigment Yellow 161 Inorganic - Titanate	77895 Nickel Niobium Titanium Yellow	68611-43-8	3	C-00126
C.I. Pigment Yellow 163 Inorganic - Titanate	77897 Chromium Tungsten Titanium Buff	68186-92-5	1	C-00992
C.I. Pigment Yellow 216 Inorganic - Titanate	Unknown Solaplex Yellow	389623-01-2; 389623	1	C-00918

Vanadate

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 184 Inorganic - Vanadate	771740 Bismuth Vanadate Yellow	14059-33-7	5	C-00900

Organic 190

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 214 Organic	Confidential	Confidential	1	C-00950

Azo

Benzimidazolone

Group 1 (orange/yellow)

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Orange 36 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	11780 Benzimidazolone Orange HSL	12236-62-3	2	C-00890

Analyzed Pigments by Chemical Category

Organic - Azo - Benzimidazolone - Group 1 (orange/yellow) -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Orange 62 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	11775 Benzimidazolone Orange H5G	52846-56-7	1	C-00935
C.I. Pigment Orange 72 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	211095 Hostaprint Orange H4GL 32	78245-94-0	1	C-00947
C.I. Pigment Yellow 120 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	11783 Benzimidazolone Yellow	29920-31-8	3	C-00146
C.I. Pigment Yellow 151 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	13980 Benzimidazolone Yellow	31837-42-0	3	C-00804
C.I. Pigment Yellow 154 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	11781 Benzimidazolone Yellow 154	68134-22-5	1	C-00939
C.I. Pigment Yellow 175 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	11784 Benizimidazolone Yellow H6G	35636-63-6	1	C-00940
C.I. Pigment Yellow 180 Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)	21290 Benzimidazolone Yellow	77804-81-0	5	C-00901
Group 2 (red/brown/violet)				
C.I. Pigment Brown 25 Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)	12510 Benzimidazolone Brown	6992-11-6	1	C-00934
C.I. Pigment Red 171 Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)	12512 Benzimidazolone Bordeaux	6985-95-1	1	C-01012
C.I. Pigment Red 175 Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)	12513 Benzimidazolone Red HFT	6985-92-8	3	C-01034
C.I. Pigment Red 176 Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)	12515 Benzimidazolone Carmine	12225-06-8	1	C-01047
C.I. Pigment Red 185 Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)	12516 Permanent Carmine HF4C	51920-12-8; 90433-30	1	C-00942
Beta-Napthol				
C.I. Pigment Orange 2 Organic - Azo - Beta-Napthol	12060 Hansa Orange RN	6410-09-9	3	C-00158

Analyzed Pigments by Chemical Category

Organic - Azo - Beta-Napthol - -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Orange 5 Organic - Azo - Beta-Napthol	12075 Hansa Orange RN	3468-63-1	5	C-00269
C.I. Pigment Red 1 Organic - Azo - Beta-Napthol	12070 Pigment Red 1	6410-10-2	3	C-00168
C.I. Pigment Red 3 Organic - Azo - Beta-Napthol	12120 Toluidine Red	2425-85-6	2	C-00527
C.I. Pigment Red 4 Organic - Azo - Beta-Napthol	12085 Permanent Red R	2814-77-9	3	C-00188

Disazo

Bisacetoacetarylide

C.I. Pigment Yellow 155 Organic - Azo - Disazo - Bisacetoacetarylide	200310 Sandorin Yellow 4G	68516-73-4; 77465-46	1	C-00984

Diarylide

C.I. Pigment Orange 16 Organic - Azo - Disazo - Diarylide	21160 Benzidine Orange	6505-28-8; 10277-04	1	C-01016
C.I. Pigment Yellow 12 Organic - Azo - Disazo - Diarylide	21090	6358-85-6	1	C-00960
C.I. Pigment Yellow 13 Organic - Azo - Disazo - Diarylide	21100 Benzidine Yellow GR	5102-83-0	2	C-00538
C.I. Pigment Yellow 14 Organic - Azo - Disazo - Diarylide	21095 Diarylide Yellow AAOT	5468-75-7	3	C-00157
C.I. Pigment Yellow 17 Organic - Azo - Disazo - Diarylide	21105 Dairylide Yellow 17	4531-49-1	3	C-00267
C.I. Pigment Yellow 55 Organic - Azo - Disazo - Diarylide	21096 Diarylide Yellow AAPT	6358-37-8	3	C-00181
C.I. Pigment Yellow 81 Organic - Azo - Disazo - Diarylide	21127 Diarylide Yellow H10G	22094-93-5	1	C-01008

Analyzed Pigments by Chemical Category

Organic - Azo - Disazo - Diarylide -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 83 Organic - Azo - Disazo - Diarylide	21108 Diarylide Yellow HR	5567-15-7	3	C-00154
C.I. Pigment Yellow 152 Organic - Azo - Disazo - Diarylide	21111 Diarylide Yellow 152	31775-20-9	3	C-00196
C.I. Pigment Yellow 170 Organic - Azo - Disazo - Diarylide	21104 Pigment Yellow FRN	31775-16-3	1	C-01009
C.I. Pigment Yellow 174 Organic - Azo - Disazo - Diarylide	21098 Irgalite Yellow LBT	78952-72-4	3	C-00183
C.I. Pigment Yellow 188 Organic - Azo - Disazo - Diarylide	21094 Irgalite Yellow	23792-68-9	3	C-00184
Disazopyrazolone				
C.I. Pigment Orange 13 Organic - Azo - Disazo - Disazopyrazolone	21110 Benzidine Orange	3520-72-7	5	C-00504
C.I. Pigment Orange 34 Organic - Azo - Disazo - Disazopyrazolone	21115 Pyrazolone Range	15793-73-4	3	C-00186
C.I. Pigment Red 38 Organic - Azo - Disazo - Disazopyrazolone	21120 Pyrazolone Red	6358-87-8	5	C-00926
Disazo Condensation				
C.I. Pigment Brown 23 Organic - Azo - Disazo Condensation	20060 Pigment Brown 23	35869-64-8	2	C-01020
C.I. Pigment Brown 41 Organic - Azo - Disazo Condensation	Confidential Sandorin Brown RL		1	C-00951
C.I. Pigment Red 144 Organic - Azo - Disazo Condensation	20735 Azo Condensation Red	5280-78-4	3	C-00268
C.I. Pigment Red 166 Organic - Azo - Disazo Condensation	20730 Azo Condensation Red	3905-19-9	3	C-00170
C.I. Pigment Red 214 Organic - Azo - Disazo Condensation	200660 Fastogen Super Red 2R	40618-31-3; 82643-43	1	C-01014

Analyzed Pigments by Chemical Category

Organic - Azo - Disazo Condensation - -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 220 Organic - Azo - Disazo Condensation	20055 Pigment Red 220	68259-05-2	2	C-01023
C.I. Pigment Red 221 Organic - Azo - Disazo Condensation	20065 Pigment Red 221	71566-54-6	2	C-01022
C.I. Pigment Red 242 Organic - Azo - Disazo Condensation	20067 Disazo Condensation Scarlet	52238-92-3	1	C-01013
C.I. Pigment Yellow 93 Organic - Azo - Disazo Condensation	20710 Disazo Yellow 3G	5580-57-4	2	C-01024
C.I. Pigment Yellow 95 Organic - Azo - Disazo Condensation	20034 Disazo Yellow GR	5280-80-8	3	C-00137
C.I. Pigment Yellow 128 Organic - Azo - Disazo Condensation	20037 Azo Condensation Yellow	79953-85-8	2	C-01025

Isoindoline

Methine

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 139 Organic - Azo - Isoindoline - Methine	56298 Isoindoline Yellow	36888-99-0	2	C-00079

Isoindolinone

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 173 Organic - Azo - Isoindolinone	561600 Isoindolinone Yellow	96352-23-7	3	C-01031

Azomethine

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Orange 61 Organic - Azo - Isoindolinone - Azomethine	11265 Isoindolol Orange	106276-78-2; 40716	1	C-01017
C.I. Pigment Yellow 109 Organic - Azo - Isoindolinone - Azomethine	56284 Isoindole Yellow	5045-40-9	3	C-01028
C.I. Pigment Yellow 110 Organic - Azo - Isoindolinone - Azomethine	56280 Isoindolinone Yellow	5590-18-1; 106276-80	1	C-01018

Metal Complex

Analyzed Pigments by Chemical Category

Organic - Azo - Metal Complex - Azo -

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
Azo				
C.I. Pigment Green 8 Organic - Azo - Metal Complex - Azo	10006 Nitroso Green	16143-80-9	1	C-01004
Nickel				
C.I. Pigment Yellow 150 Organic - Azo - Metal Complex - Azo	12764 Nickel Azo Yellow	68511-62-6	2	C-00803
Azomethine				
C.I. Pigment Orange 68 Organic - Azo - Metal Complex - Azomethine	486150 Sandorin Orange	42844-93-9	1	C-00946
C.I. Pigment Yellow 129 Organic - Azo - Metal Complex - Azomethine	48042 Irgazin Yellow	15680-42-9	3	C-01029
C.I. Pigment Yellow 153 Organic - Azo - Metal Complex - Azomethine	48545 Nickel Dioxime Yellow	29204-84-0	4	C-00668
Monoazo				
Deviated				
C.I. Pigment Yellow 10 Organic - Azo - Monoazo - Deviated	12710 Hansa Yellow Rq	6407-75-6	3	C-00147
C.I. Pigment Yellow 60 Organic - Azo - Monoazo - Deviated	12705	6407-74-5	3	C-00166
General				
C.I. Pigment Yellow 1 Organic - Azo - Monoazo - General	11680 Hansa Yellow G	2512-29-0	3	C-00798
C.I. Pigment Yellow 3 Organic - Azo - Monoazo - General	11710 Hansa Yellow 10G	6486-23-3	3	C-00800
C.I. Pigment Yellow 6 Organic - Azo - Monoazo - General	11670 Hansa Yellow 3G	4106-76-7	3	C-01027

Analyzed Pigments by Chemical Category

Organic - Azo - Monoazo - General -

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 65	11740	6528-34-3	2	C-00539
Organic - Azo - Monoazo - General	Hansa Yellow 65			
C.I. Pigment Yellow 73	11738	13515-40-7	2	C-00899
Organic - Azo - Monoazo - General	Arylide Yellow GX			
C.I. Pigment Yellow 74	11741	6358-31-2	2	C-00868
Organic - Azo - Monoazo - General	Arylide Yellow 74			
C.I. Pigment Yellow 75	11770	52320-66-8	5	C-00207
Organic - Azo - Monoazo - General	Arylide Yellow			
C.I. Pigment Yellow 97	11767	12225-18-2	5	C-00205
Organic - Azo - Monoazo - General	Diarylide Yellow			
C.I. Pigment Yellow 111	11745	15993-42-7	3	C-00182
Organic - Azo - Monoazo - General	Hansa Brilliant Yellow			

Lakes

Deviated

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 100	19140:1	12225-21-7	3	C-00095
Organic - Azo - Monoazo - Lakes	Tartrazine Lake			
C.I. Pigment Yellow 183	18792	65212-77-3	3	C-00139
Organic - Azo - Monoazo - Lakes	Paliotol Yellow K227			
C.I. Pigment Yellow 191	18795	129423-54-7	1	C-00948
Organic - Azo - Monoazo - Lakes				
C.I. Pigment Yellow 191:1	18795:1	154946-66-4	1	C-01019
Organic - Azo - Monoazo - Lakes	Cromophtal Yellow			

General

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 61	13880	12286-65-6	1	C-00982
Organic - Azo - Monoazo - Lakes				
C.I. Pigment Yellow 62	13940	12286-66-7	2	C-00904
Organic - Azo - Monoazo - Lakes	Pigment Yellow 62			

Analyzed Pigments by Chemical Category

Organic - Azo - Monoazo - Lakes - General

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 168 Organic - Azo - Monoazo - Lakes	13960 Azo Yellow 168	71832-85-4	3	C-00190
C.I. Pigment Yellow 169 Organic - Azo - Monoazo - Lakes	13955 Lionol Yellow K-2R	73385-03-2	3	C-00191

Naphthol AS

Group 1

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 2 Organic - Azo - Naphthol AS - Group 1	12310 Nathohol Red G	6041-94-7	3	C-00187
C.I. Pigment Red 8 Organic - Azo - Naphthol AS - Group 1	12335 Permanent Red F4R	6410-30-6	1	C-01042
C.I. Pigment Red 9 Organic - Azo - Naphthol AS - Group 1	12460 Naphthol AS Red	6410-38-4	3	C-00149
C.I. Pigment Red 12 Organic - Azo - Naphthol AS - Group 1	12385 Permanent Bordeaux TRR	6410-32-8	3	C-00189
C.I. Pigment Red 13 Organic - Azo - Naphthol AS - Group 1	12395 Toluidine Maroon	6535-47-3	1	C-01010
C.I. Pigment Red 17 Organic - Azo - Naphthol AS - Group 1	12390 Pigment Red 17	6655-84-1	2	C-00534
C.I. Pigment Red 21 Organic - Azo - Naphthol AS - Group 1	12300 Pigment Red 21	6410-26-0	1	C-01043
C.I. Pigment Red 22 Organic - Azo - Naphthol AS - Group 1	12315 Naphthol Bright Red	6448-95-9	3	C-00164
C.I. Pigment Red 23 Organic - Azo - Naphthol AS - Group 1	12355 Naphthol Red Dark	6471-49-4	2	C-00532
C.I. Pigment Red 112 Organic - Azo - Naphthol AS - Group 1	12370 Naphthol Red ASD	6535-46-2	2	C-00858

Group 2

Analyzed Pigments by Chemical Category

Organic - Azo - Naphthol AS - Group 2 -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Orange 38 Organic - Azo - Naphthol AS - Group 2	12367 Naphthol Orange	12236-64-5	3	C-00150
C.I. Pigment Red 5 Organic - Azo - Naphthol AS - Group 2	12490 Naphthol Red DK	6410-41-9	3	C-00405
C.I. Pigment Red 31 Organic - Azo - Naphthol AS - Group 2	12360 Naphthol Red Extra Dark	6448-96-0	1	C-01044
C.I. Pigment Red 146 Organic - Azo - Naphthol AS - Group 2	12485 Naphthol Red AS	5280-68-2	2	C-00907
C.I. Pigment Red 170 Organic - Azo - Naphthol AS - Group 2	12475	2786-76-7	2	C-00908
C.I. Pigment Red 184 Organic - Azo - Naphthol AS - Group 2	12487 Permanent Rubine F6G	99402-80-9	2	C-00910
C.I. Pigment Red 187 Organic - Azo - Naphthol AS - Group 2	12486	59487-23-9	1	C-00943
C.I. Pigment Red 188 Organic - Azo - Naphthol AS - Group 2	12467 Naphthol Scarlet Lake	61847-48-1	4	C-00461
C.I. Pigment Red 210 Organic - Azo - Naphthol AS - Group 2	12477; 12475; 12474 PR 210	61932-63-6	3	C-00151
C.I. Pigment Red 253 Organic - Azo - Naphthol AS - Group 2	12375 Graphtol Red GLF	85776-13-2	3	C-00152
C.I. Pigment Red 266 Organic - Azo - Naphthol AS - Group 2	12474 Permanent Red P-F7RK	2786-76-7	2	C-00923
C.I. Pigment Red 268 Organic - Azo - Naphthol AS - Group 2	12316 Permanent Scarlet OA	16403-84-2	2	C-00919
C.I. Pigment Red 269 Organic - Azo - Naphthol AS - Group 2	12466 Naphthol Red RA 1087	67990-05-0	1	C-01049

Red Azo Pigment Lakes

Beta Oxynaphthoic Acid Lake

Analyzed Pigments by Chemical Category

Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 47 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	Unknown Fast Orange FR	160828-79-5	1	C-00972
C.I. Pigment Red 57:2 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15850:2	17852-98-1	1	C-00964
Barium				
C.I. Pigment Red 48:1 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15865:1 Permanent Red BB	7585-41-3	2	C-00535
Calcium				
C.I. Pigment Red 48:2 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15865:2 Permanent Red BB	7023-61-2	1	C-00977
C.I. Pigment Red 52:1 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15860:1 Pigment Red 52:1	17852-99-	2	C-00528
C.I. Pigment Red 57:1 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15850:1 Lithol Rubine	5281-04-9	2	C-00530
C.I. Pigment Red 63:1 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15880:1 Lithol Bordeaux	6417-83-0	5	C-00906
C.I. Pigment Red 200 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15867 Radiant Red	58067-05-3	5	C-00111
Manganese				
C.I. Pigment Red 48:4 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15865:4 Permanent Red 2B	5280-66-0	1	C-00979
C.I. Pigment Red 52:2 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15860:2	12238-31-2	1	C-00978
Strontium				
C.I. Pigment Red 48:3 Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake	15865:3 Irgalite Red 2BY	15782-05-5	3	C-00491

Beta-Napthol Lake

Analyzed Pigments by Chemical Category

Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake - Barium

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
Barium				
C.I. Pigment Orange 46	15602	63467-26-5	2	C-00920
Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake	Pigment Orange 46			
C.I. Pigment Red 49:1	15630:1	1103-38-4	2	C-00529
Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake	Barium Lithol Red			
C.I. Pigment Red 53:1	15585:1	2092-56-0	2	C-00533
Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake	Pigment Lake Red C			
Calcium				
C.I. Pigment Red 49:2	15630:2	1103-39-5	3	C-00744
Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake	Calcium Lithol Red			
Sodium				
C.I. Pigment Red 53	15585	2092-56-0	5	C-00215
Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake	Lake Red C			
Naphthalene Sulfonic Acid Lakes				
Aluminum				
C.I. Pigment Red 273	16035:1	68583-95-9	1	C-00967
Organic - Azo - Red Azo Pigment Lakes - Naphthalene Sulfonic Acid Lakes	FD&C Red 40 Alum Lake			
C.I. Pigment Yellow 104	15985:1	15790-07-5	3	C-00171
Organic - Azo - Red Azo Pigment Lakes - Naphthalene Sulfonic Acid Lakes	FD&C Yellow 6			
Barium				
C.I. Pigment Red 60:1	16105:1	1325-16-2	3	C-00173
Organic - Azo - Red Azo Pigment Lakes - Naphthalene Sulfonic Acid Lakes	Pigment Scarlet			
Naphthol AS Lakes				
Calcium				
C.I. Pigment Red 247	15915	43035-18-3	1	C-00944
Organic - Azo - Red Azo Pigment Lakes - Naphthol AS Lakes				

Other

Analyzed Pigments by Chemical Category

Organic - Other - - -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Black 1 Organic - Other	50440 Aniline Black	13007-86-8	3	C-00218
C.I. Pigment Orange 107 Organic - Other	Unknown Pigment Orange 107	N/A	2	C-00090
C.I. Pigment Red 90:1 Organic - Other	45380:3 Geranium lake	15876-39-8	1	C-00966
C.I. Pigment Yellow 182 Organic - Other	128300 Sandorin Yellow	67906-31-4	3	C-00805
Azoheterocyclus				
C.I. Pigment Orange 64 Organic - Other - Azoheterocyclus	12760	72102-84-2	1	C-00945
Monoazo Chinazolodian				
C.I. Pigment Yellow 213 Organic - Other - Monoazo Chinazolodian	117875	220198-21-0	1	C-00941
Polycyclic				
Aminoanthraquinone				
C.I. Pigment Red 177 Organic - Polycyclic - Aminoanthraquinone	65300 Anthradquinone Red	4051-63-2	2	C-00909
C.I. Pigment Yellow 147 Organic - Polycyclic - Aminoanthraquinone	60645 Pigment Yellow 147	4118-16-5	3	C-00138
Dikeopyrrolo-Pyrrole (DPP)				
C.I. Pigment Orange 71 Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)	561200 Pyrrole Orange	84632-50-8	1	C-01006
C.I. Pigment Orange 73 Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)	561170 Pyrrole Orange	84632-59-7; 71832-85	5	C-00389
C.I. Pigment Red 254 (α) Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)	56110 Pyrrole Red	122390-98-1 / 84632	4	C-00084

Analyzed Pigments by Chemical Category

Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP) - -

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 255	561050	120500-90-5	2	C-00089
Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)	Pyrrole Scarlet			
C.I. Pigment Red 264	561300	177265-40-5	2	C-00088
Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)	Pyrrole Red Rubrine			
C.I. Pigment Red 272	561150		1	C-01015
Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)	C.I. Pigment Red 272			

Dioxazine

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Violet 23 (α (tentative))	51319	6358-30-1	4	C-00694
Organic - Polycyclic - Dioxazine	Dioxazine Violet			
C.I. Pigment Violet 23 (β)	51319	6358-30-1	2	C-00878
Organic - Polycyclic - Dioxazine	Dioxazine Violet			
C.I. Pigment Violet 37	51345	57971-98-9	3	C-01033
Organic - Polycyclic - Dioxazine	Dioxazine Violet			

Heterocyclic Anthraquinone

Anthrapyrimidine

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 108	68420	4216-01-7	4	C-00564
Organic - Polycyclic - Heterocyclic Anthraquinone - Anthrapyrimidine	Anthrapyrimidine Yellow			

Flavanthrone

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Yellow 24	70600	475-71-8	1	C-01007
Organic - Polycyclic - Heterocyclic Anthraquinone - Flavanthrone	Flaventhrone Yellow			

Indanthrone

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Blue 60	69800	81-77-6	1	C-00975
Organic - Polycyclic - Heterocyclic Anthraquinone - Indanthrone				

Hydroxyanthraquinone

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 83	56000	104074-25-1	3	C-00404
Organic - Polycyclic - Hydroxyanthraquinone	Alizarin Crimson			

Analyzed Pigments by Chemical Category

Organic - Polycyclic - Hydroxyanthraquinone - -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 83:1 Organic - Polycyclic - Hydroxyanthraquinone	58000:1 Alizarin Lake	104074-25-1	2	C-00174
C.I. Pigment Violet 5:1 Organic - Polycyclic - Hydroxyanthraquinone	58055:1 Quinazarine Super Maroon	1328-04-7 / 16508-74	3	C-00178
Perinone				
C.I. Pigment Orange 43 Organic - Polycyclic - Perinone	71105 Perinone Orange	4424-06-0	2	C-00924
C.I. Pigment Red 194 Organic - Polycyclic - Perinone	71100 Perinone Red	4216-02-8	3	C-01035
Perylene				
C.I. Pigment Black 32 Organic - Polycyclic - Perylene	71133 Perylene Black	83524-75-8	1	C-00952
C.I. Pigment Red 123 Organic - Polycyclic - Perylene	71145 Perylene Scarlet	24108-89-2	2	C-00860
C.I. Pigment Red 149 Organic - Polycyclic - Perylene	71137 Perylene Red BX	4948-15-6	3	C-00208
C.I. Pigment Red 178 Organic - Polycyclic - Perylene	71155 Perylene Red	3049-71-6	3	C-00216
C.I. Pigment Red 179 Organic - Polycyclic - Perylene	71130 Perylene Maroon	5521-31-3	2	C-00856
C.I. Pigment Red 190 Organic - Polycyclic - Perylene	71140 Perylene Scarlet	6424-77-7	2	C-00830
C.I. Pigment Red 224 Organic - Polycyclic - Perylene	71127 Perylene Red	128-69-8	2	C-00834
C.I. Pigment Violet 29 Organic - Polycyclic - Perylene	71129 Perylene Violet	81-33-4	2	C-00880
Phthalocyanine				

Analyzed Pigments by Chemical Category

Organic - Polycyclic - Phthalocyanine - -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Blue 15 Organic - Polycyclic - Phthalocyanine	74160 Phthalocyanine Blue	147-14-8	3	C-00302
C.I. Pigment Green 7 Organic - Polycyclic - Phthalocyanine	74260 Phthalocyanine Green BS	1328-53-6	1	C-00332
C.I. Pigment Green 36 Organic - Polycyclic - Phthalocyanine	74265 Phthalocyanine Green YS	14302-13-7	1	C-00333
alpha				
C.I. Pigment Blue 15:1 Organic - Polycyclic - Phthalocyanine - alpha	74160 Phthalocyanine Blue RS	12239-87-1, 147-14-8	2	C-00305
C.I. Pigment Blue 15:2 Organic - Polycyclic - Phthalocyanine - alpha	74160 Phthalocyanine Blue	147-14-8	2	C-00304
beta				
C.I. Pigment Blue 15:3 Organic - Polycyclic - Phthalocyanine - beta	74160 Phthalocyanine Blue BGS	147-14-8	2	C-00300
C.I. Pigment Blue 15:4 Organic - Polycyclic - Phthalocyanine - beta	74160 Phthalocyanine Blue NCF	147-14-8	2	C-00301
gamma				
C.I. Pigment Blue 15:6 Organic - Polycyclic - Phthalocyanine - gamma	74160 Phthalocyanine Blue	147-14-8	2	C-00895
Polycarbocyclic Anthraquinone				
Anthanthrone				
C.I. Pigment Red 168 Organic - Polycyclic - Polycarbocyclic Anthraquinone - Anthanthrone	59300 Anthraquinone Scarlet	4378-61-4	2	C-00829
Pyranthrone				
C.I. Pigment Orange 51 Organic - Polycyclic - Polycarbocyclic Anthraquinone - Pyranthrone	Unknown Pyranthrone Orange	61512-61-6	3	C-01039

Quinacridone

Analyzed Pigments by Chemical Category

Organic - Polycyclic - Quinacridone - -

C.I. Generic Name Chemical Categorization	Constitution Number Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 122 Organic - Polycyclic - Quinacridone	73915 Quinacridone Red	980-26-7 / 16043-40-6	2	C-00828
C.I. Pigment Red 202 Organic - Polycyclic - Quinacridone	73907 Quinacridone Crimson	3089-17-6	2	C-00062
C.I. Pigment Red 209 Organic - Polycyclic - Quinacridone	73905 Quinacridone Red	38720-66-0; 3573-01	1	C-00937
C.I. Pigment Violet 19 (β) Organic - Polycyclic - Quinacridone	73900	1047-16-1	1	C-00936
Quinone				
C.I. Pigment Orange 48 Organic - Polycyclic - Quinacridone - Quinone	73900 Quinacridone Gold	1047-16-1; 1503-48-6;	3	C-01036
C.I. Pigment Orange 49 Organic - Polycyclic - Quinacridone - Quinone	73900 Quinacridone Deep Gold	71819-75-5	3	C-01037
Quinophthalone				
C.I. Pigment Yellow 138 Organic - Polycyclic - Quinophthalone	56300 Quinophthalone Yellow	30125-47-4	5	C-00903
Thioindigo ***Indigo, unsubstituted***				
C.I. Pigment Blue 66 Organic - Polycyclic - Thioindigo - Indigo, unsubstituted	73000 Indigo	482-89-3	4	C-00458
Substituted				
C.I. Pigment Red 88 Organic - Polycyclic - Thioindigo - Substituted	73312 Thioindigoid Voilet	14295-43-3	2	C-00859

Triarylcarbonium

Dye salts with complex anions

Analyzed Pigments by Chemical Category

Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions - Group 1 (123)

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
Group 1 (123)				
C.I. Pigment Blue 1	42595:2	1325-87-7	3	C-00852
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Victoria Blue			
C.I. Pigment Blue 1:2	42595:3	69980-72-9	1	C-00974
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Victoria Blue SMA			
C.I. Pigment Blue 10	44040:2	1325-93-5	1	C-01005
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions				
C.I. Pigment Blue 78	42090:2	68921-42-6	1	C-00970
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions				
C.I. Pigment Green 1	42040:1	1325-75-3	4	C-00640
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Pigment Green 1			
C.I. Pigment Green 4	42000:2	61725-50-6	3	C-00101
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	3606 Fast Green Lake			
C.I. Pigment Violet 3	42535	1325-82-2	5	C-00116
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Methyl Violet			
C.I. Pigment Violet 27	42535:3	12237-62-6; 25869-00	1	C-00976
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Fanal Violet BKF			
Group 2 (124)				
C.I. Pigment Red 81	45160:1	12224-98-5	1	C-01045
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Rhodamine 6G			
C.I. Pigment Red 81:1	45160:3	80083-40-5	1	C-00986
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Rhodamine 6G			
C.I. Pigment Red 81:3	45161:2	68310-07-6	1	C-01011
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Rhodamine YS			
C.I. Pigment Red 81:5	45160:4	63022-06-0	1	C-00981
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions				
C.I. Pigment Red 169	45160:2	12237-63-7	1	C-00927
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Rhodamine			

Analyzed Pigments by Chemical Category

Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions - Group 2 (124)

C.I. Generic Name / Chemical Categorization	Constitution Number / Common Name	CAS Number	Q.I.	MT Pigment Number
C.I. Pigment Red 173	45170:3	12227-77-9	3	C-00105
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Rhodamine Red			
C.I. Pigment Red 174	45410:2	15876-58-1	1	C-00968
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Phloxine B			
C.I. Pigment Violet 1	45170:2	1326-03-0	2	C-00921
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Rhodamine Violet			
C.I. Pigment Violet 1:X	45710:x	63022-09-3	1	C-00973
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Rhodamine B			
C.I. Pigment Violet 2	45175:1	1326-04-1	1	C-00988
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions				
Group 3 (125)				
C.I. Pigment Green 2	42040:1	12213-69-3	1	C-00989
Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions	Fast Green Lake			
Inner salts of sulfonic acid				
C.I. Pigment Blue 61	42765:1	1324-76-1	3	C-00252
Organic - Polycyclic - Triarylcarbonium - Inner salts of sulfonic acid	Modorant Blue R			

APPENDIX B – RAMAN SPECTRA OF PIGMENTS

Pigment Classification by Chemistry

Inorganic

- **Aluminate**
- **Carbon**
- **Carbonate**
- **Chromate**
- **Cyanide**
- **Hydroxide**
- **Metal**
- **Nitro**
- **Oxide**
- **Phosphate**
- **Silicate**
- **Stannate**
- **Sulfate**
- **Sulfide**
- **Titanate**
- **Vanadate**

Organic

<u>Azo</u>

- **Benzimidazolone**
  - Group 1 (Orange/Yellow)
  - Group 2 (Red/Brown/Violet)
- **β-Naphthol**
- **Disazo**
  - Bisacetoacetarylide
  - Diarylide
  - Disazopyrazolone
- **Disazo Condensation**
- **Isoindoline**
  - Methine
- **Isoindolinone**
  - Azomethine
- **Metal Complex**
  - Azo
    - *Nickel*
  - Azomethine
- **Monoazo**
  - Deviated
  - Genereal
  - Lakes
    - *Deviated*
    - *General*
- **Naphthol AS**
  - Group 1
  - Group 2
- **Red Azo Pigment Lakes**
  - β-Oxynaphthoic Acid Lake (BONA)
    - *Barium*
    - *Calcium*
    - *Manganese*
    - *Strontium*
  - β-Naphthol Lake
    - *Barium*
    - *Calcium*
    - *Sodium*
  - Naphthalene Sulfonic Acid Lakes
    - *Aluminum*
    - *Barium*
  - Naphthol AS Lakes
    - *Calcium*

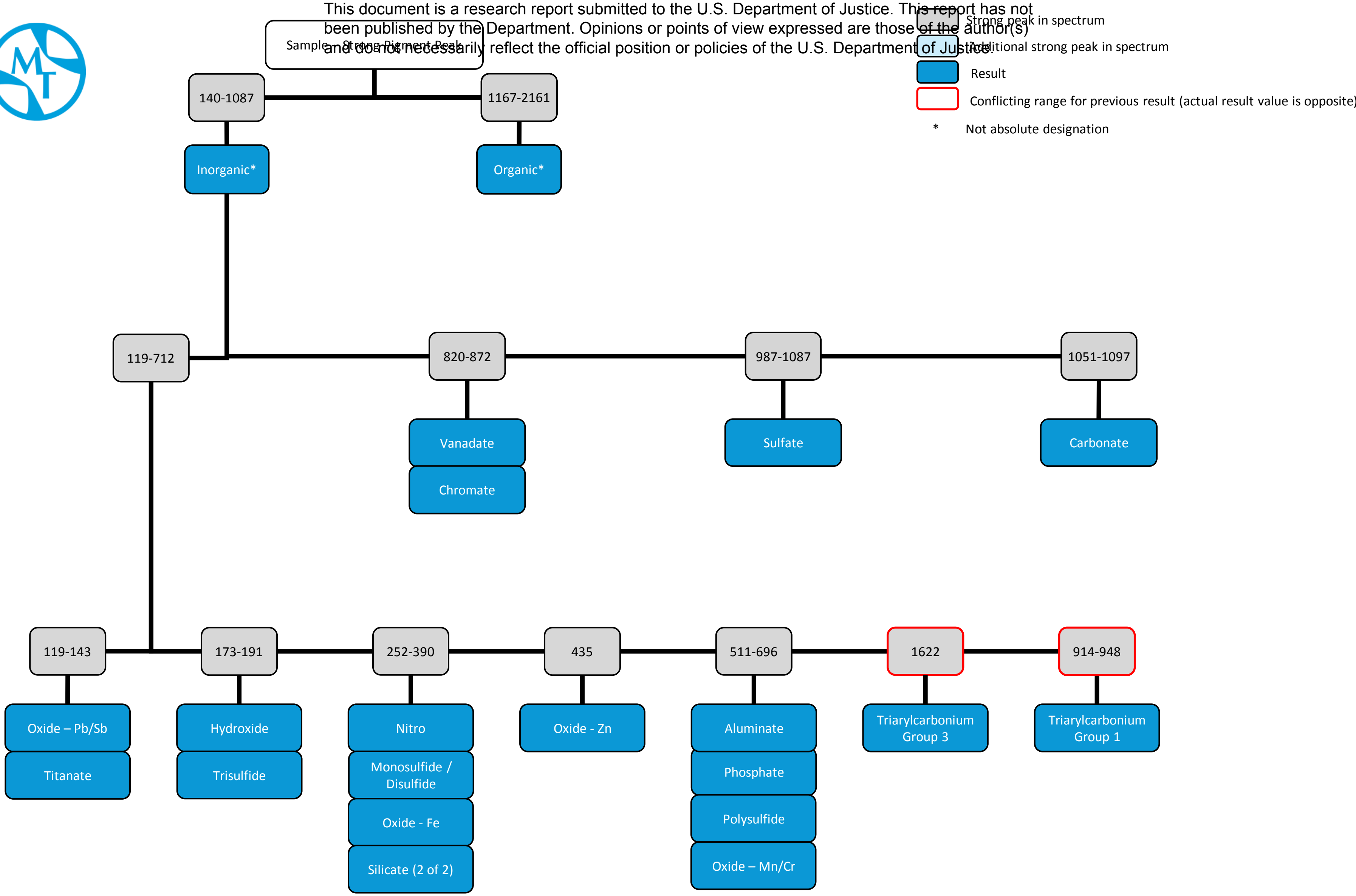
<u>Polycyclic</u>

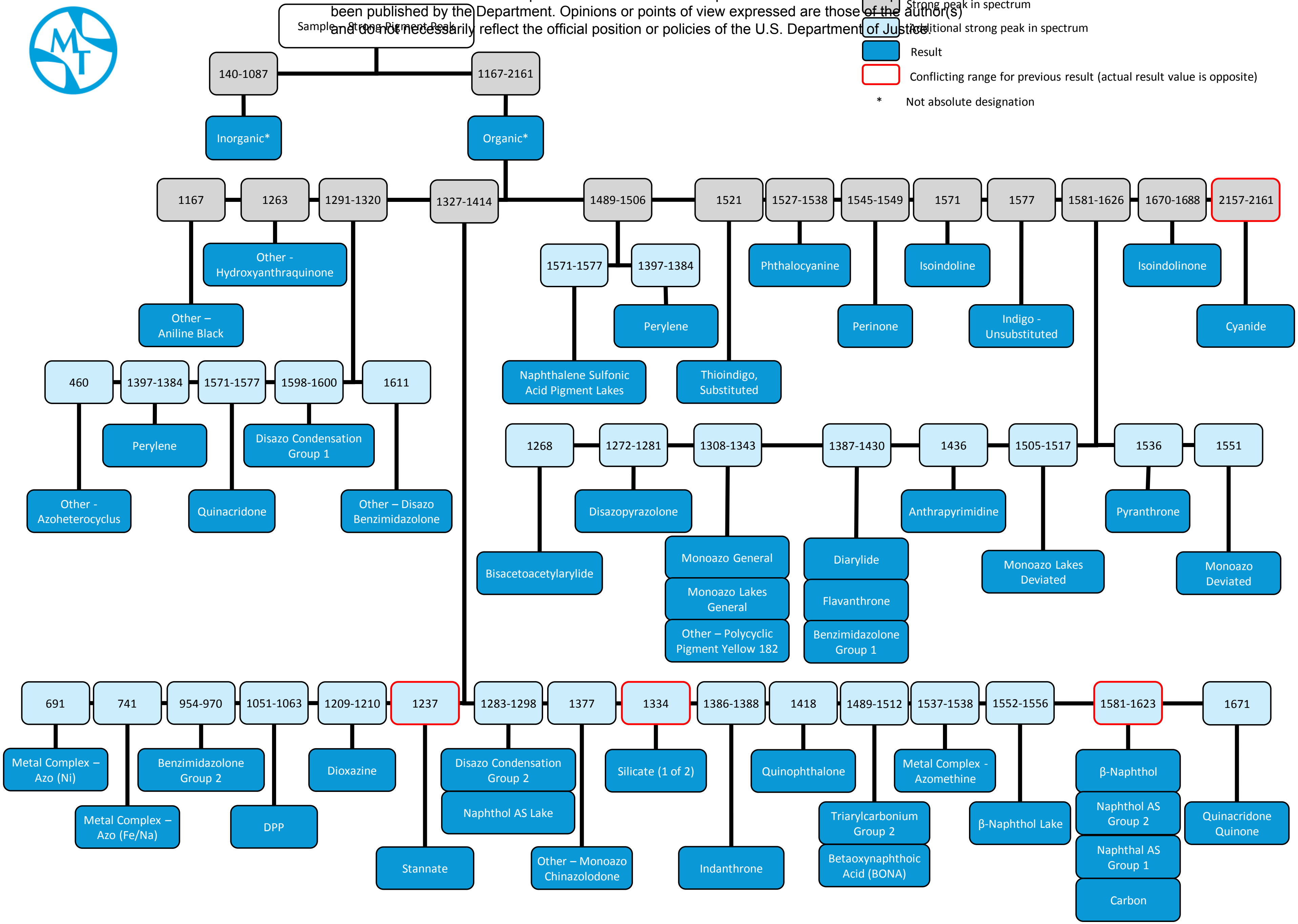
- **Aminoanthraquinone**
- **Diketopyrrolo-Pyrrole (DPP)**
- **Dioxazine**
- **Heterocyclic Anthraquinone**
  - Anthrapyrimidine
  - Flavanthrone
  - Indanthrone
- **Hydroxyanthraquinone**
- **Perinone**
- **Perylene**
- **Phthalocyanine**
  - Alpha
  - Beta
  - Gamma
- **Polycarboxylic Anthraquinone**
  - Anthanthrone
  - Pyranthrone
- **Quinacridone**
  - Quinone
- **Quinophthalone**
- **Thioindigo**
  - Indigo, unsubstituted
  - Substituted
- **Triarylcarbonium**
  - Dye Salts with Complex Anions
    - *Group 1 (123)*
    - *Group 2 (124)*
    - *Group 3 (125)*
  - Inner Salts of Sulfonic Acid

<u>Other</u>

- **Azoheterocyclus**
- **Monoazo Chinazolodian**

APPENDIX C – PIGMENT CHEMICAL CATEGORIES


Sample – Strong Pigment Peak
Strong peak in spectrum
Additional strong peak in spectrum
Result
Conflicting range for previous result (actual result value is opposite)
* Not absolute designation
140-1087
1167-2161
Inorganic*
Organic*
119-712
820-872
987-1087
1051-1097
Vanadate
Chromate
Sulfate
Carbonate
119-143
173-191
252-390
435
511-696
1622
914-948
Oxide – Pb/Sb
Titanate
Hydroxide
Trisulfide
Nitro
Monosulfide / Disulfide
Oxide - Fe
Silicate (2 of 2)
Oxide - Zn
Aluminate
Phosphate
Polysulfide
Oxide – Mn/Cr
Triarylcarbonium Group 3
Triarylcarbonium Group 1



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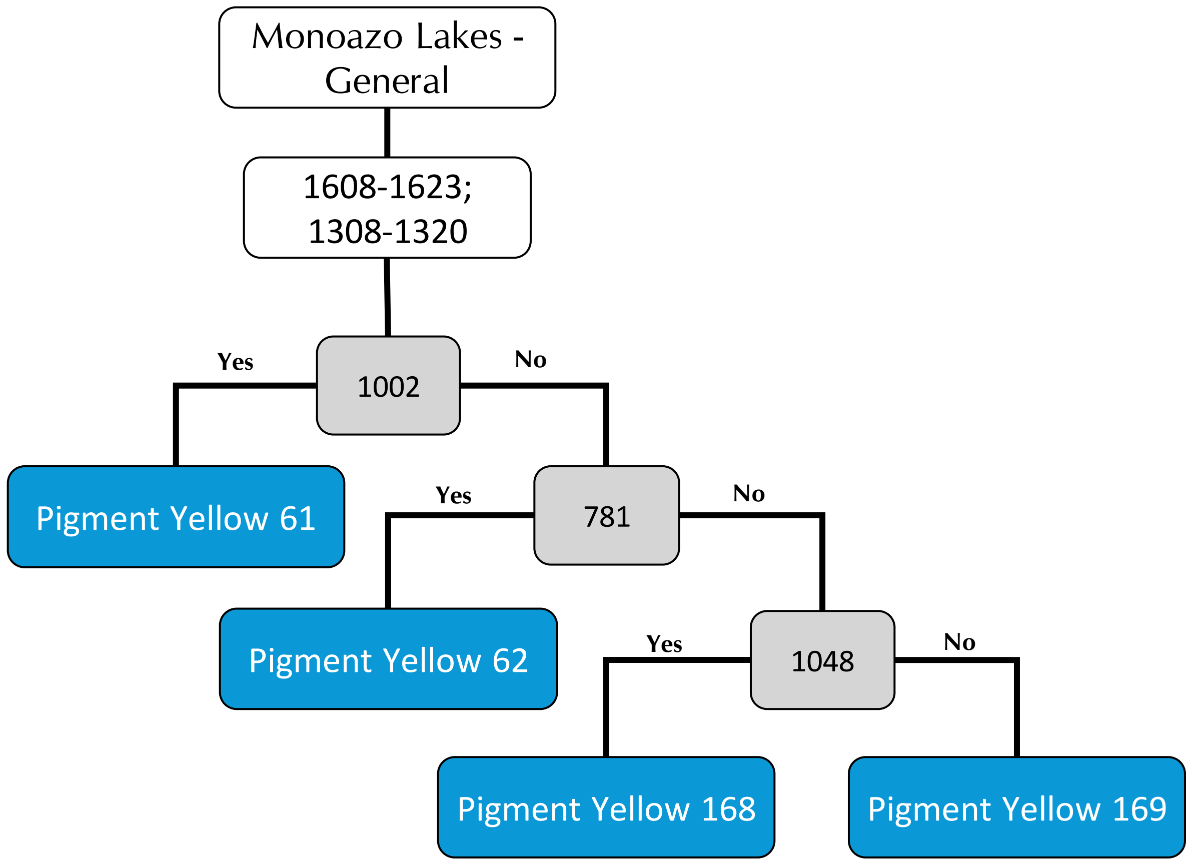
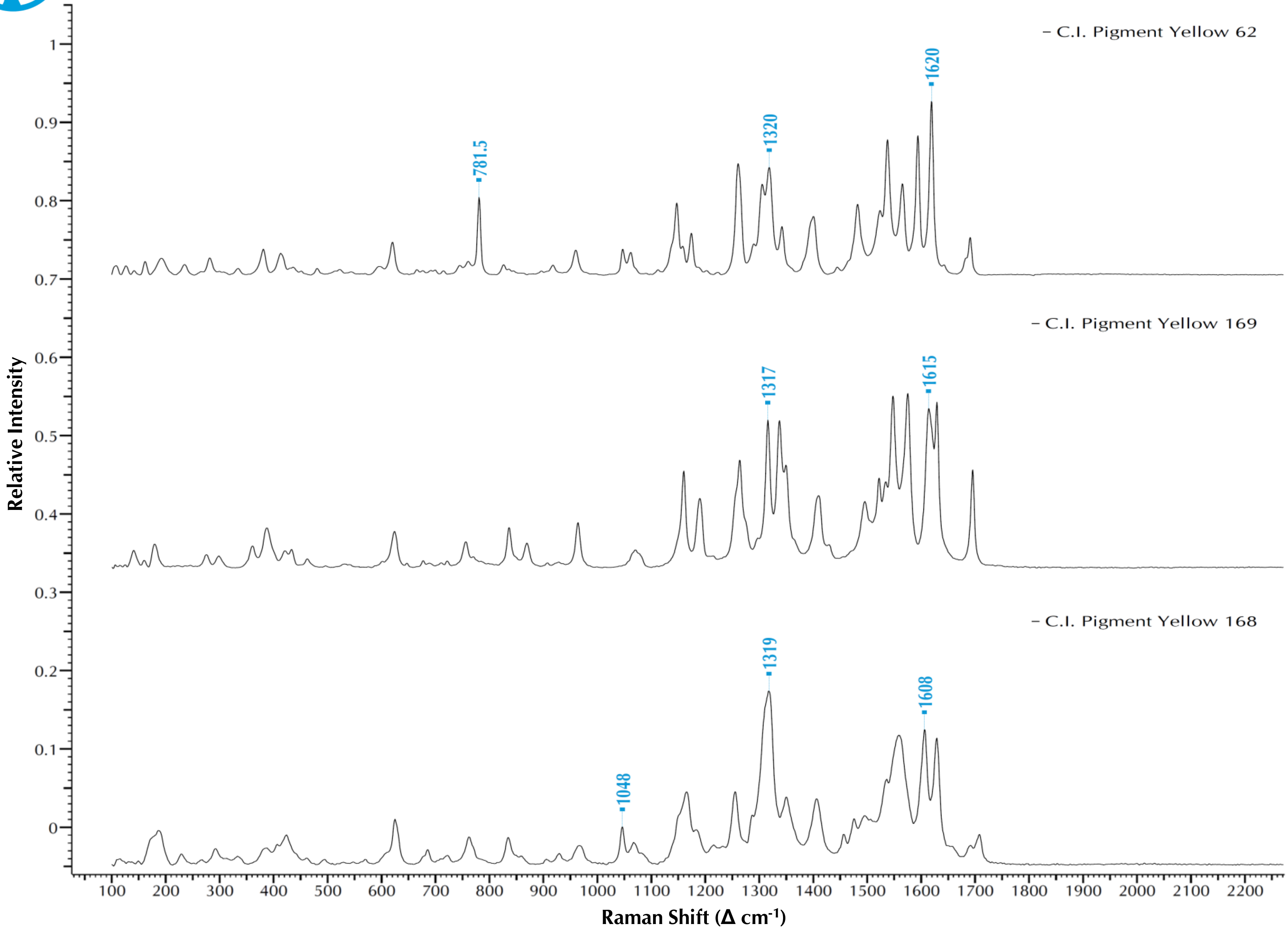
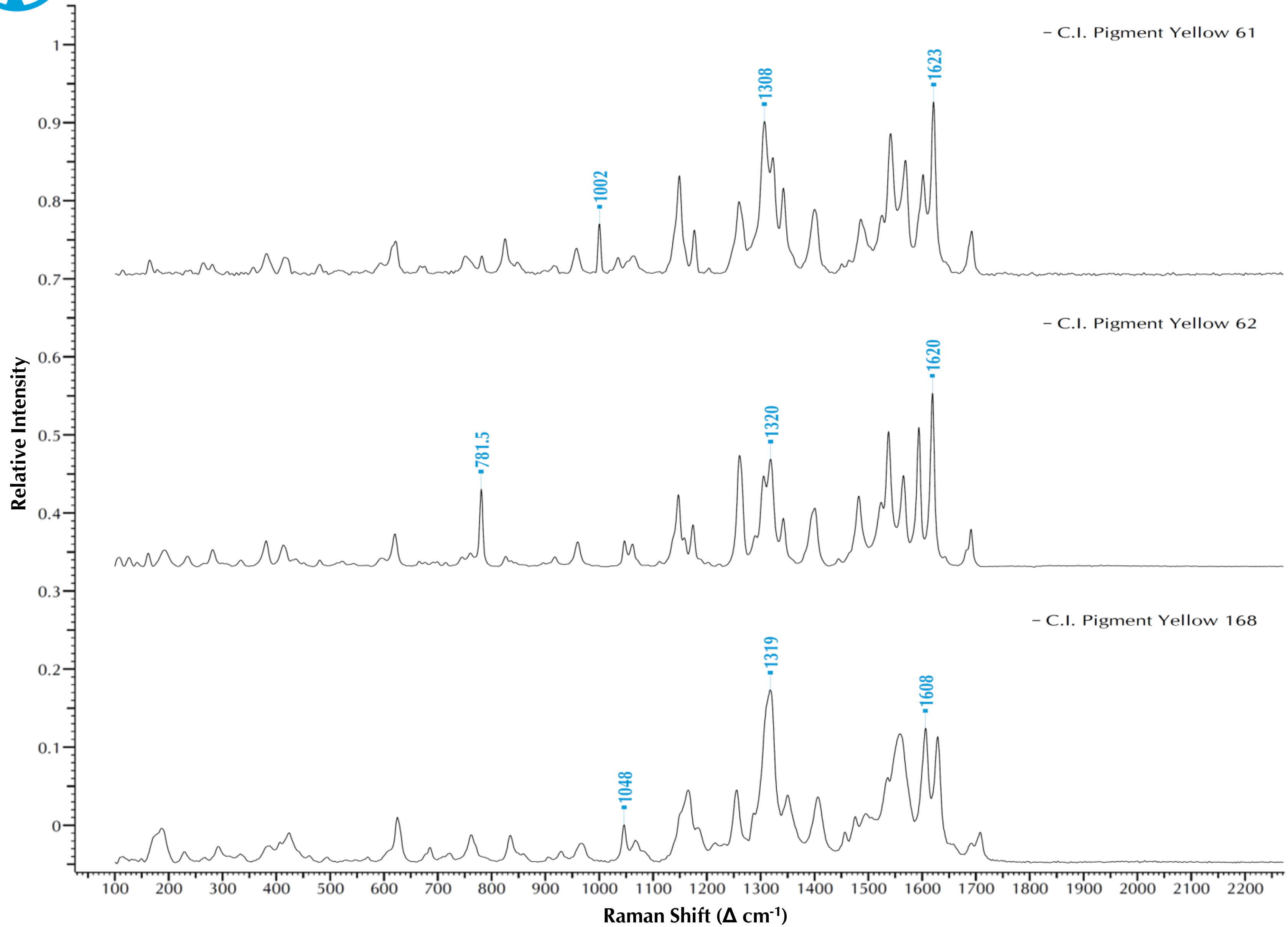
Monoazo Lakes - General



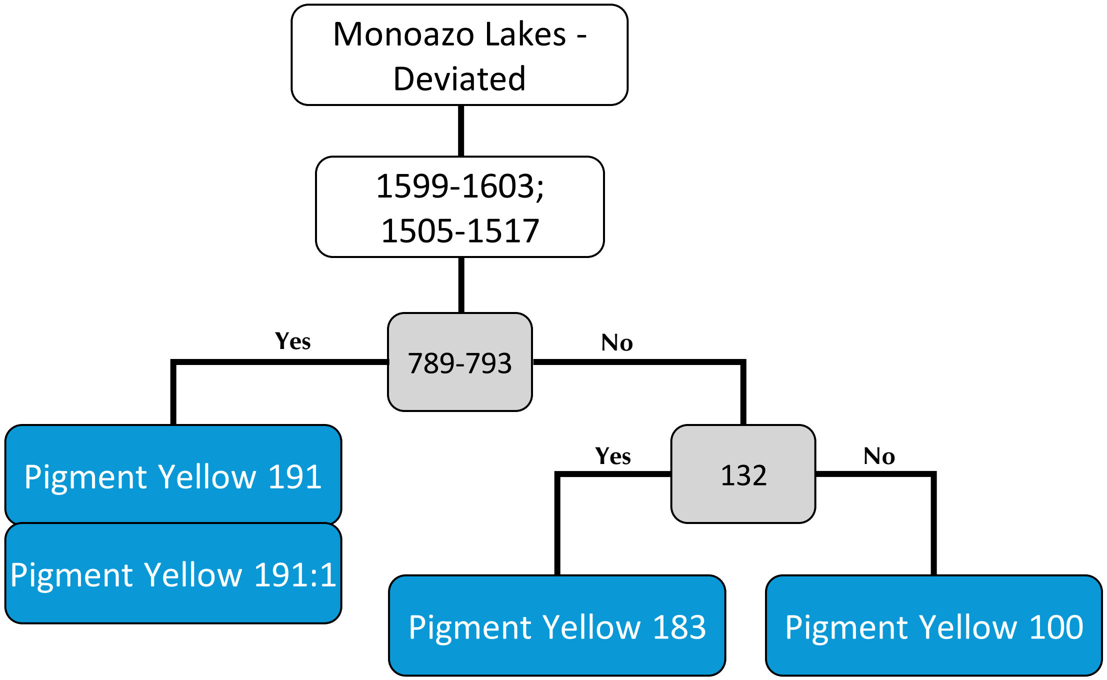
Monoazo Lakes - General



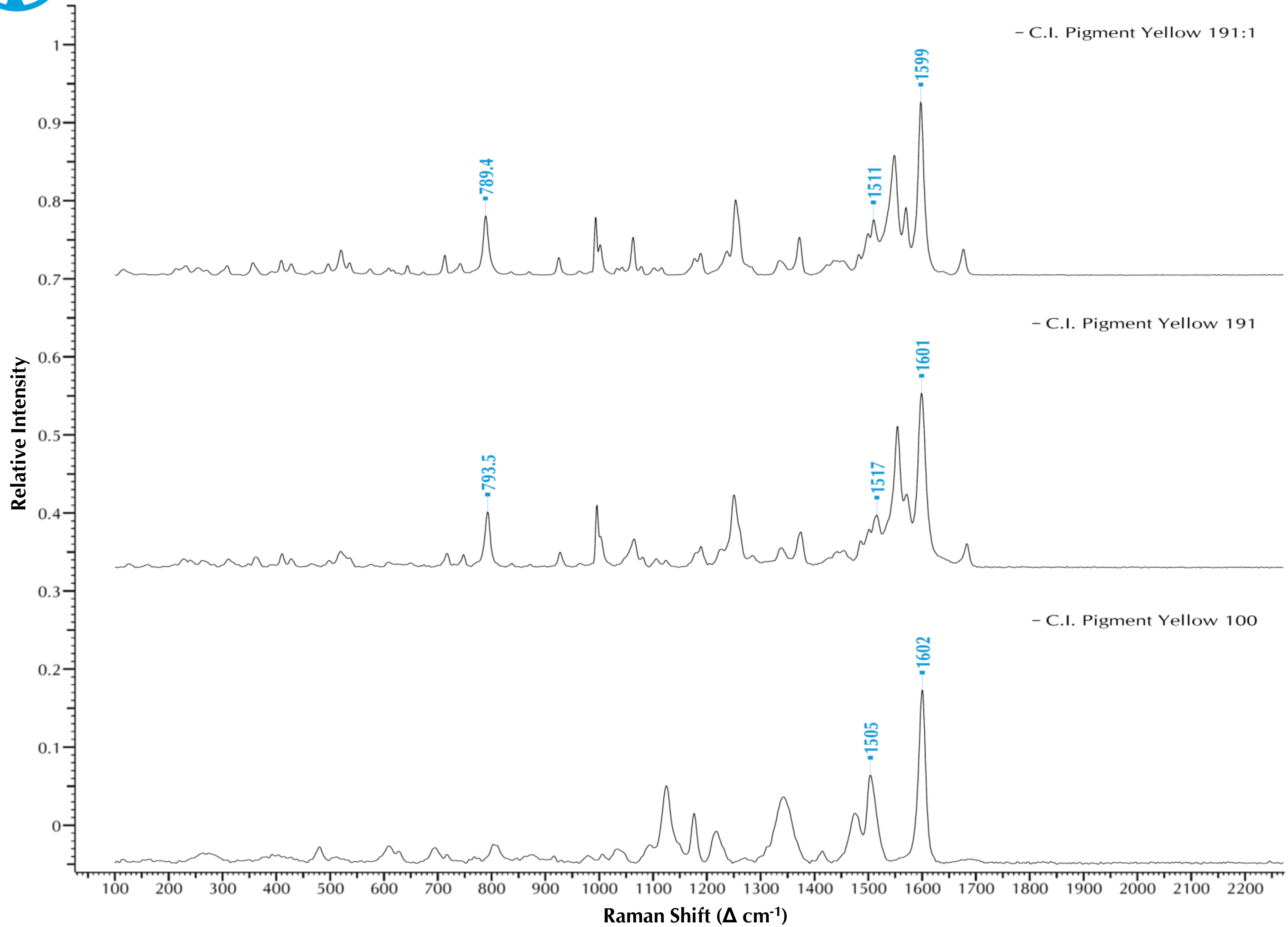
Monoazo Lakes - General



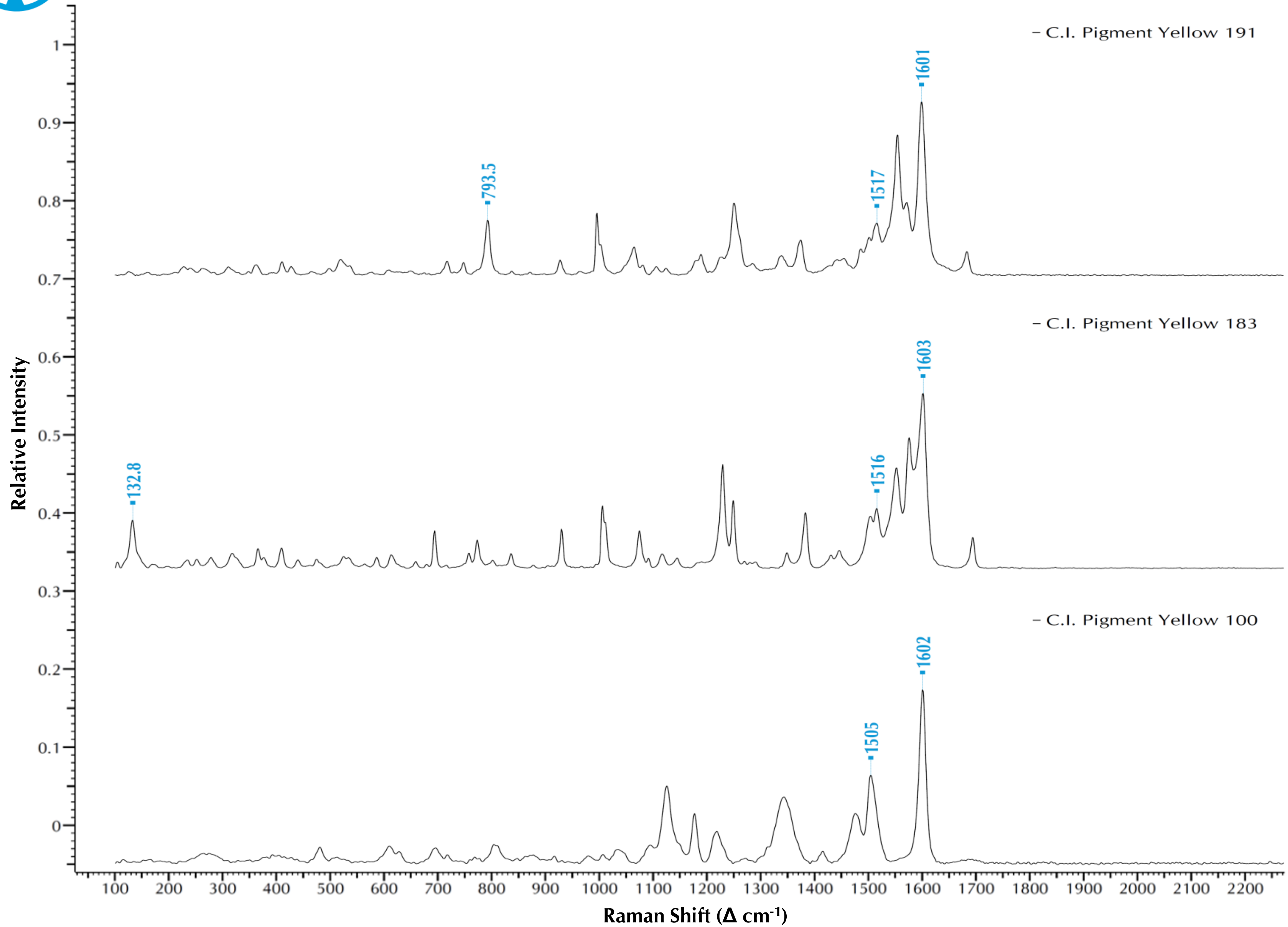
Monoazo Lakes - Deviated



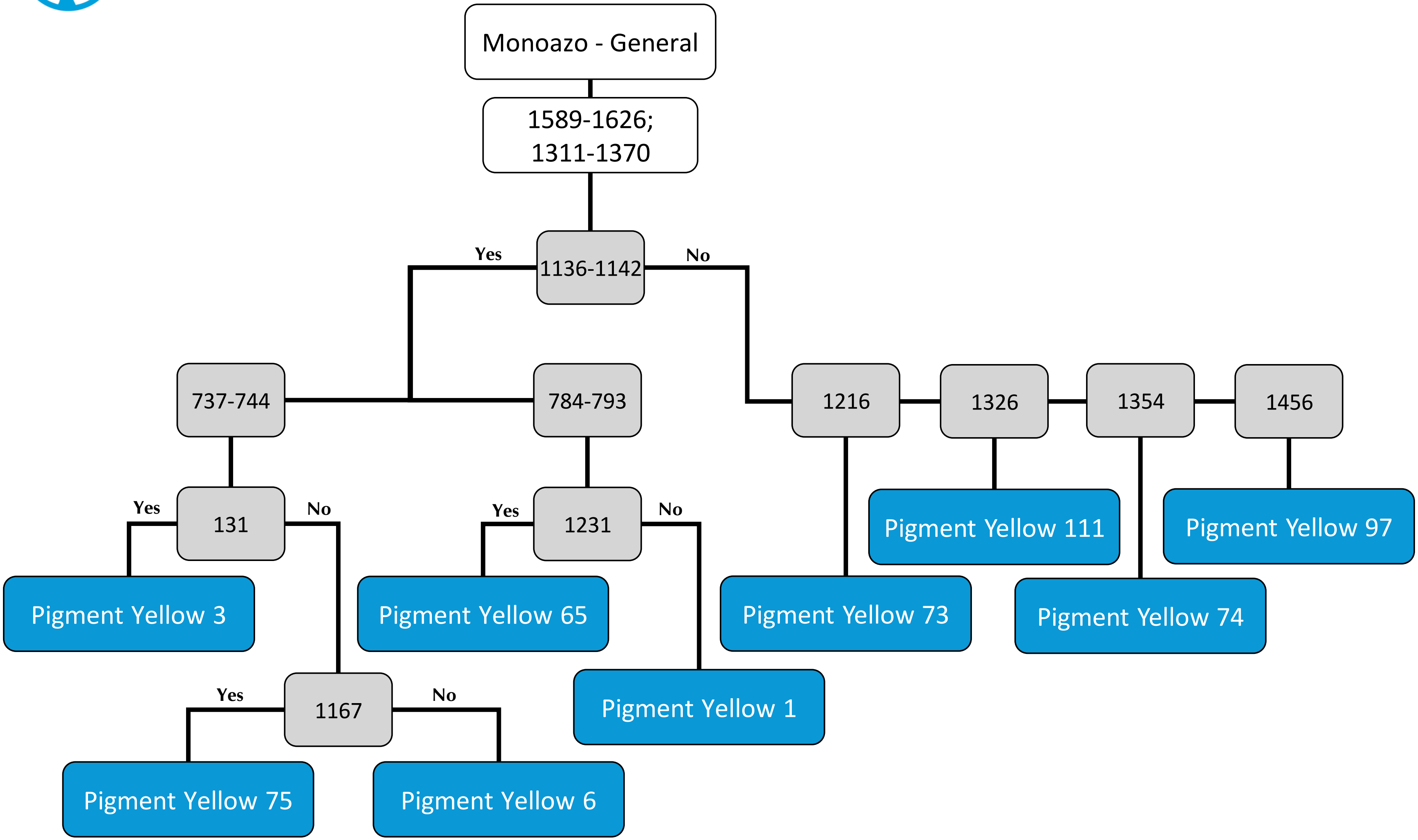
Monoazo Lakes - Deviated



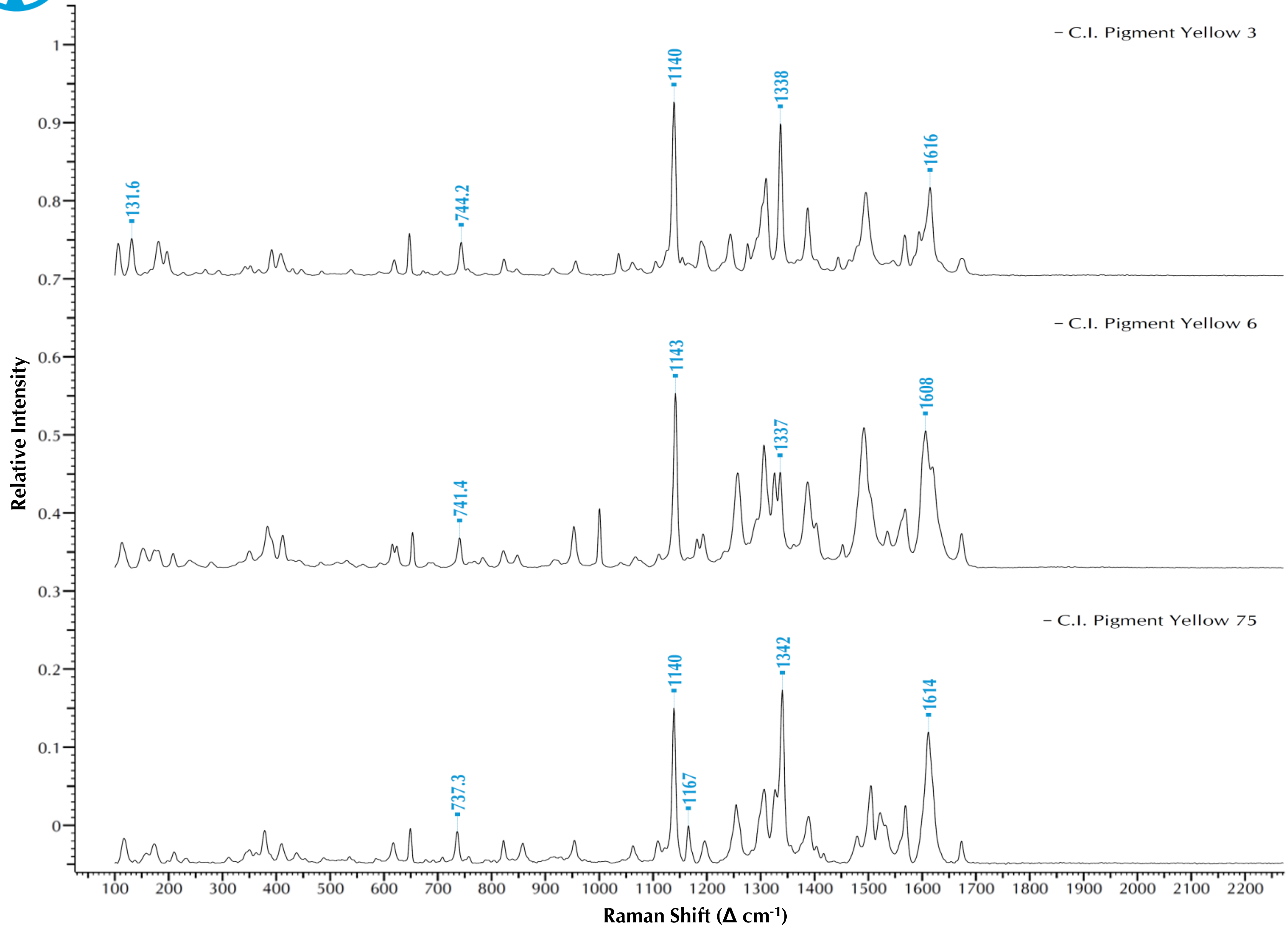
Monoazo Lakes - Deviated



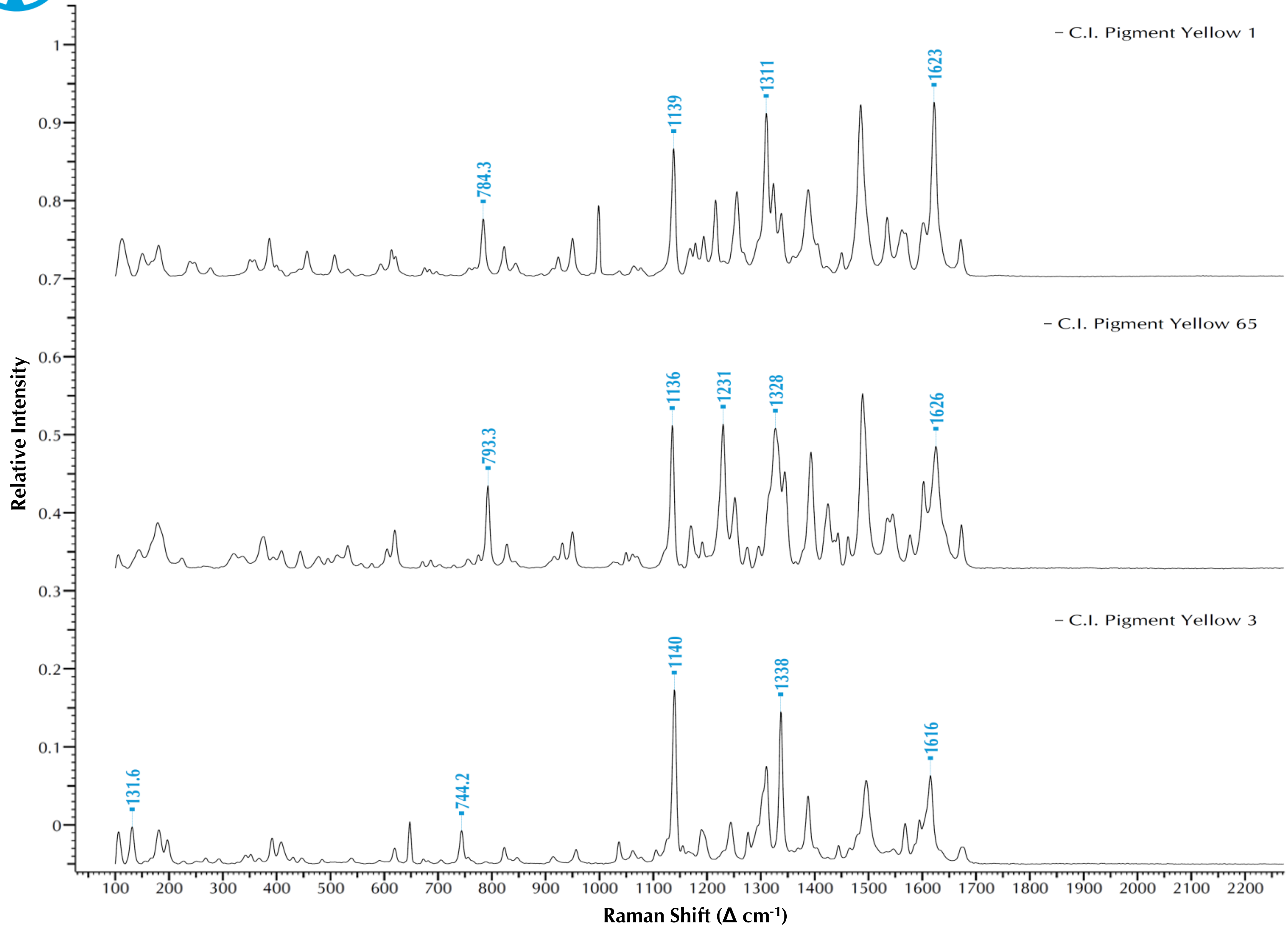
Monoazo - General



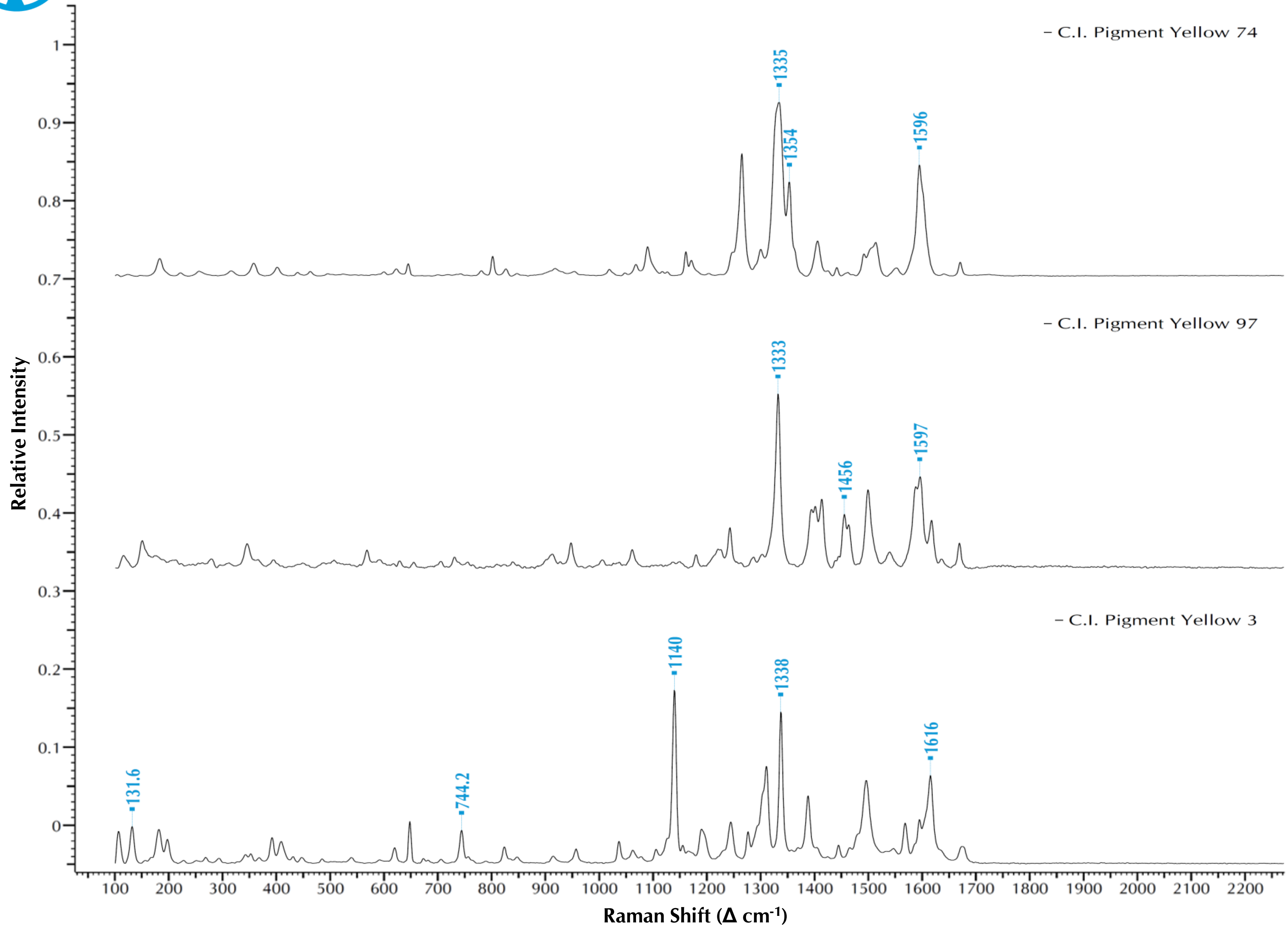
Monoazo - General



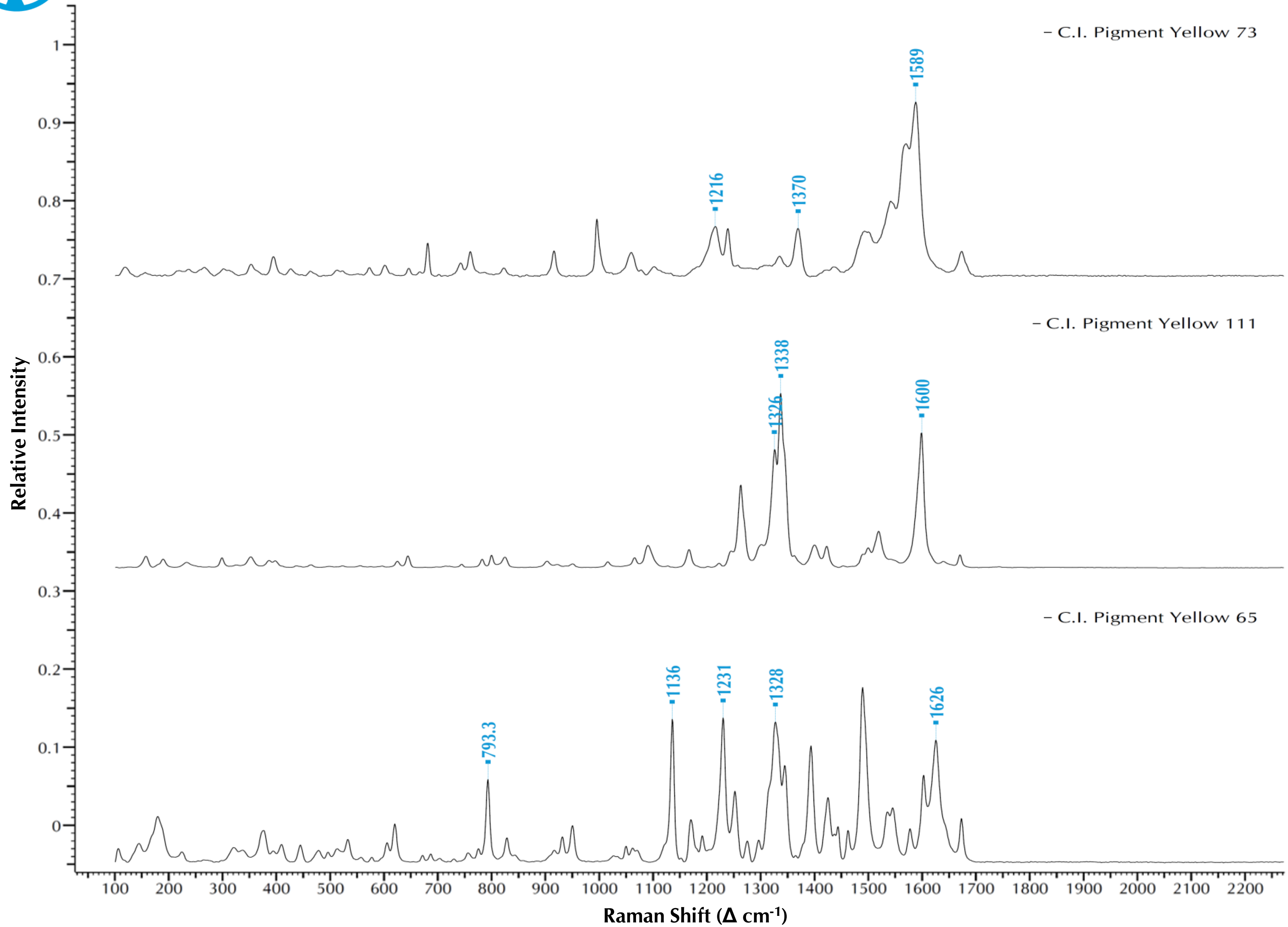
Monoazo - General



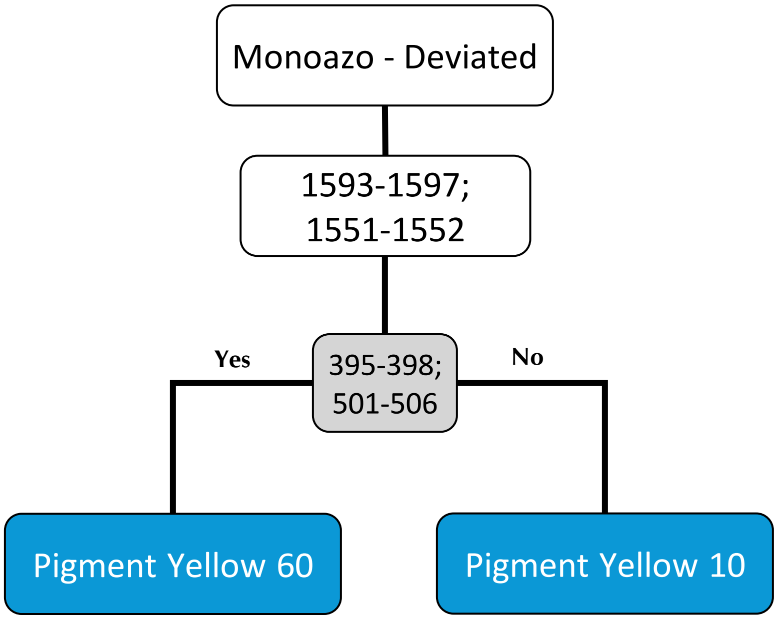
Monoazo - General



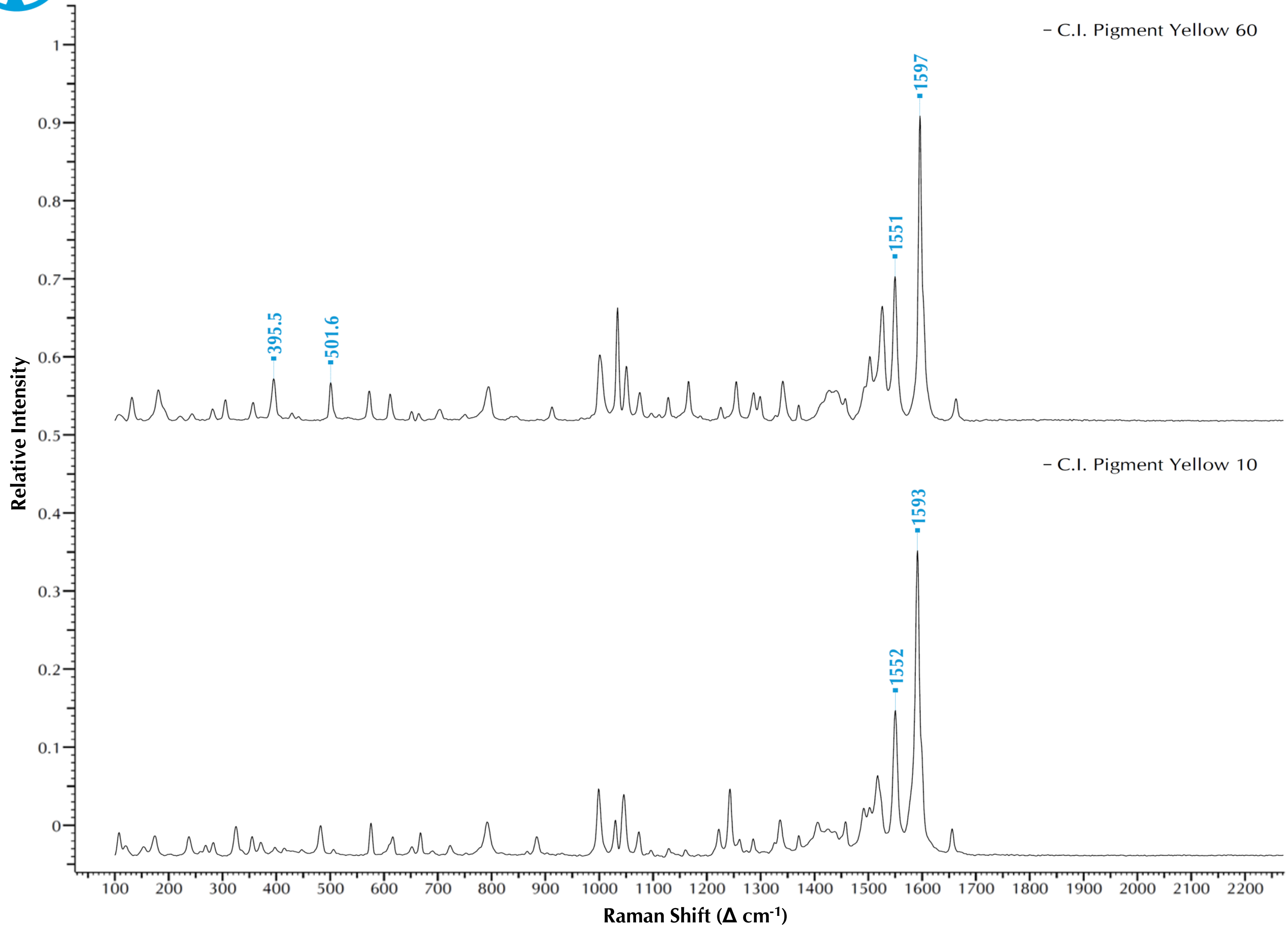
Monoazo - General



Monoazo - Deviated



Monoazo - Deviated



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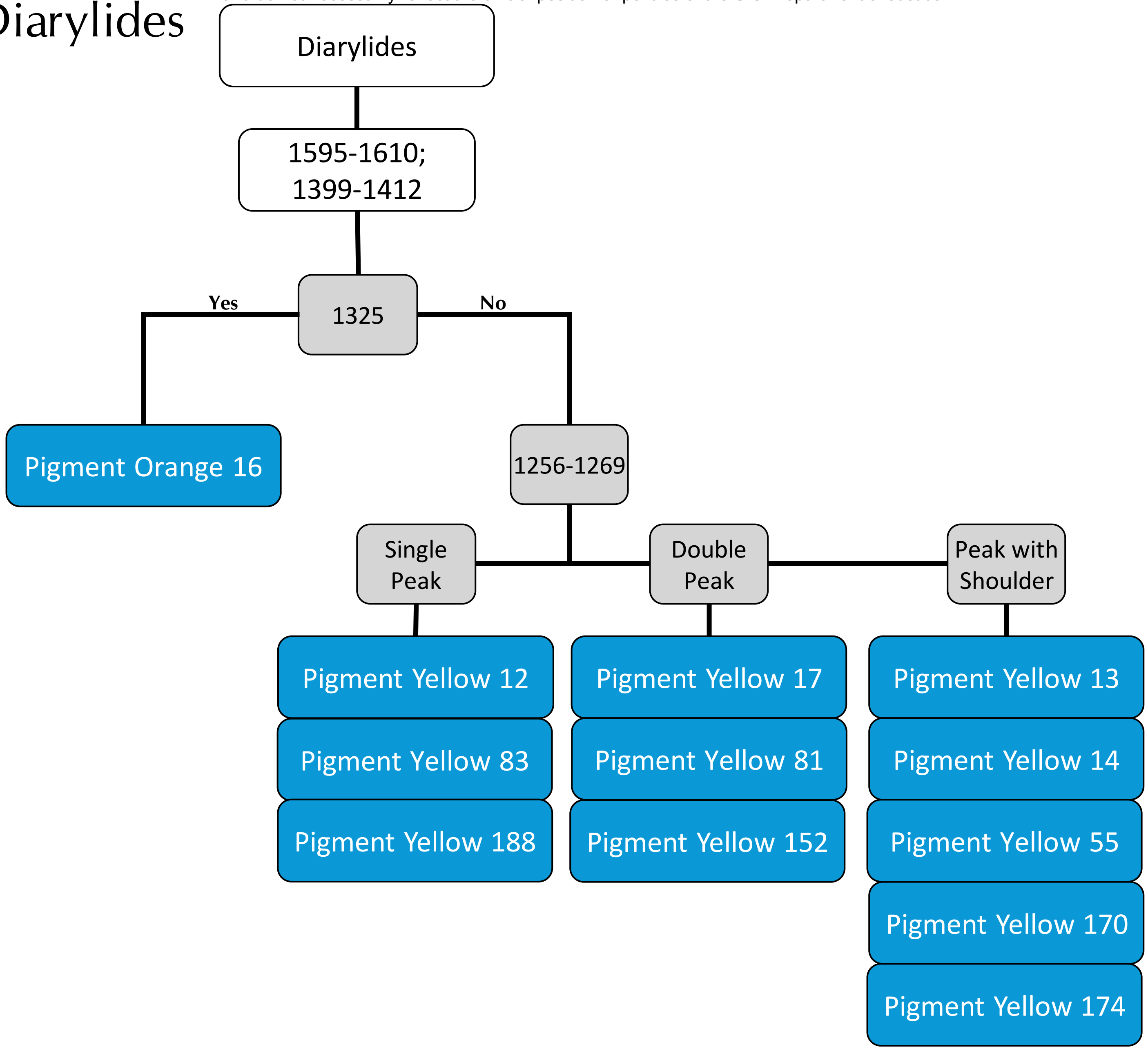
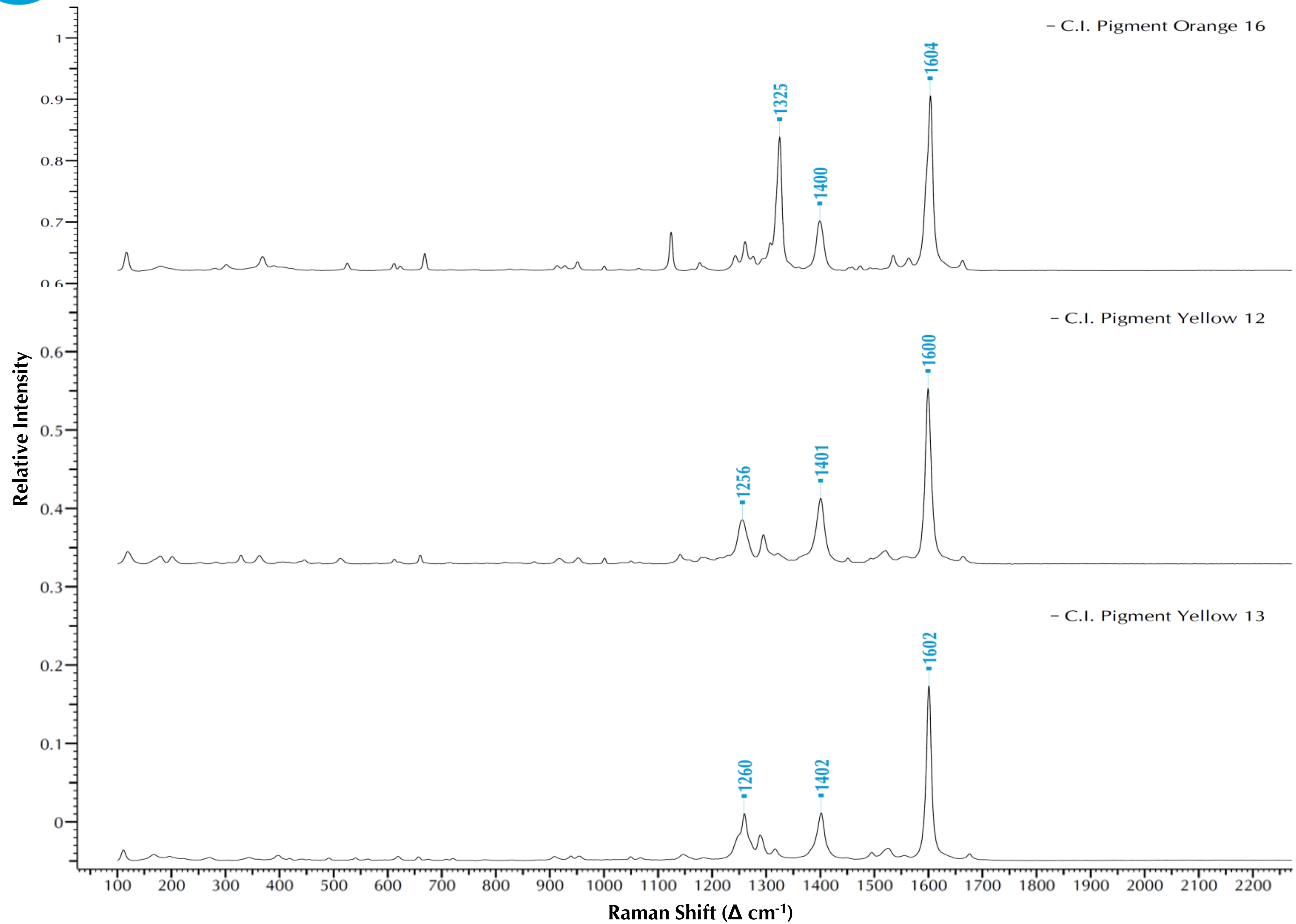
Diarylides



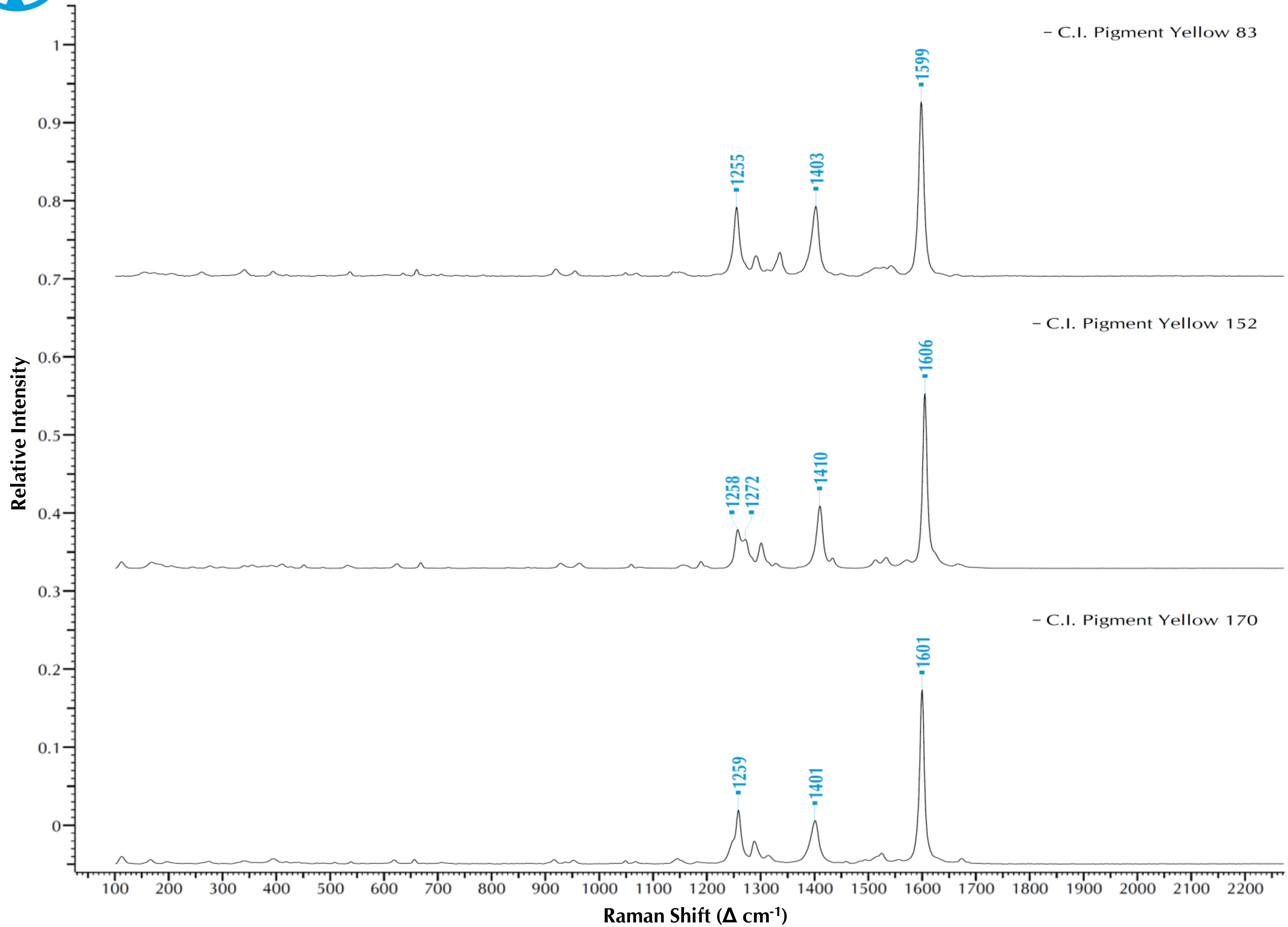
Diarylides
1595-1610; 1399-1412
1325
Yes
No
Pigment Orange 16
1256-1269
Single Peak
Double Peak
Peak with Shoulder
Pigment Yellow 12
Pigment Yellow 83
Pigment Yellow 188
Pigment Yellow 17
Pigment Yellow 81
Pigment Yellow 152
Pigment Yellow 13
Pigment Yellow 14
Pigment Yellow 55
Pigment Yellow 170
Pigment Yellow 174

Diarylides



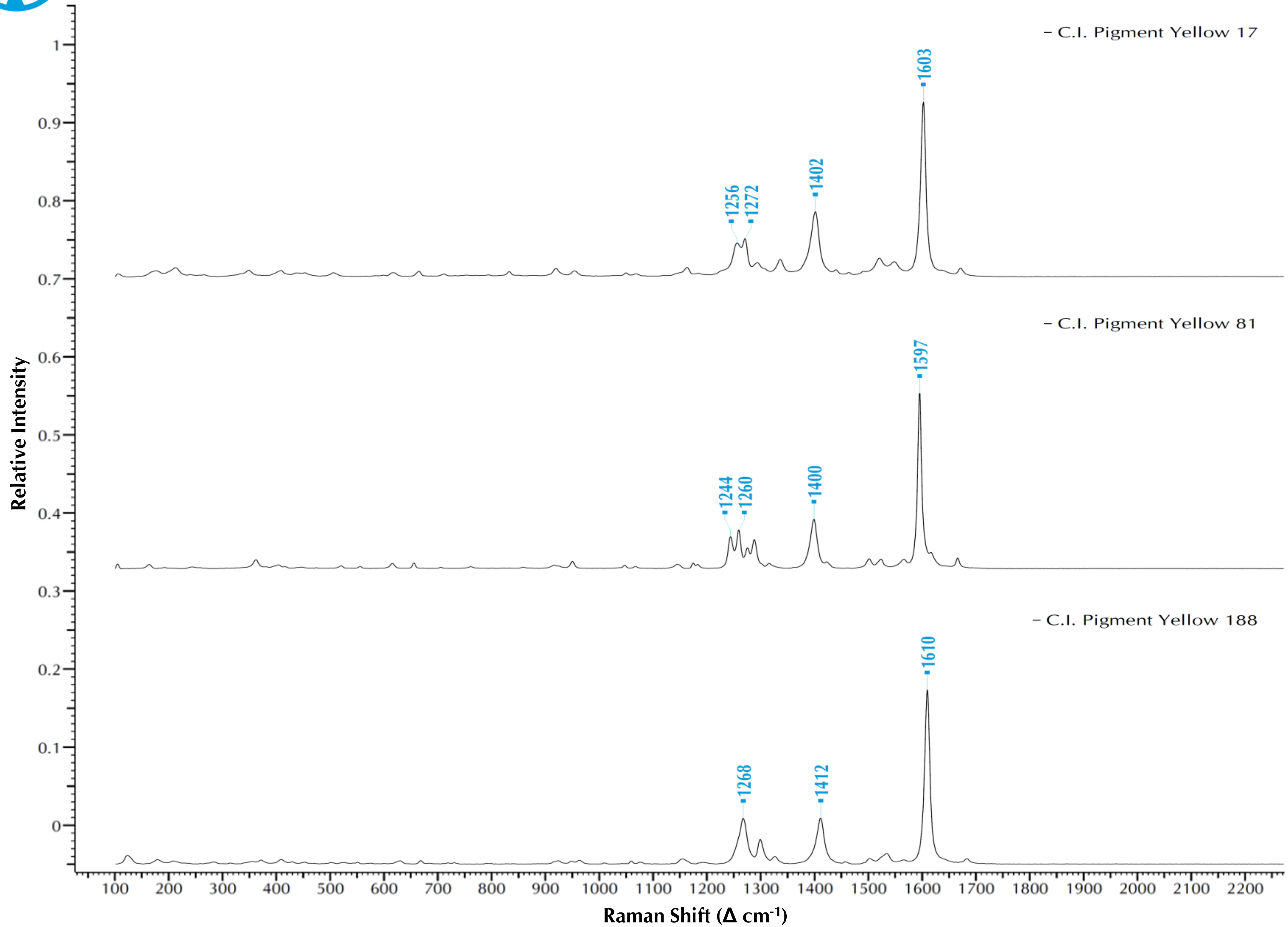
Microtrace LLC

Diarylides



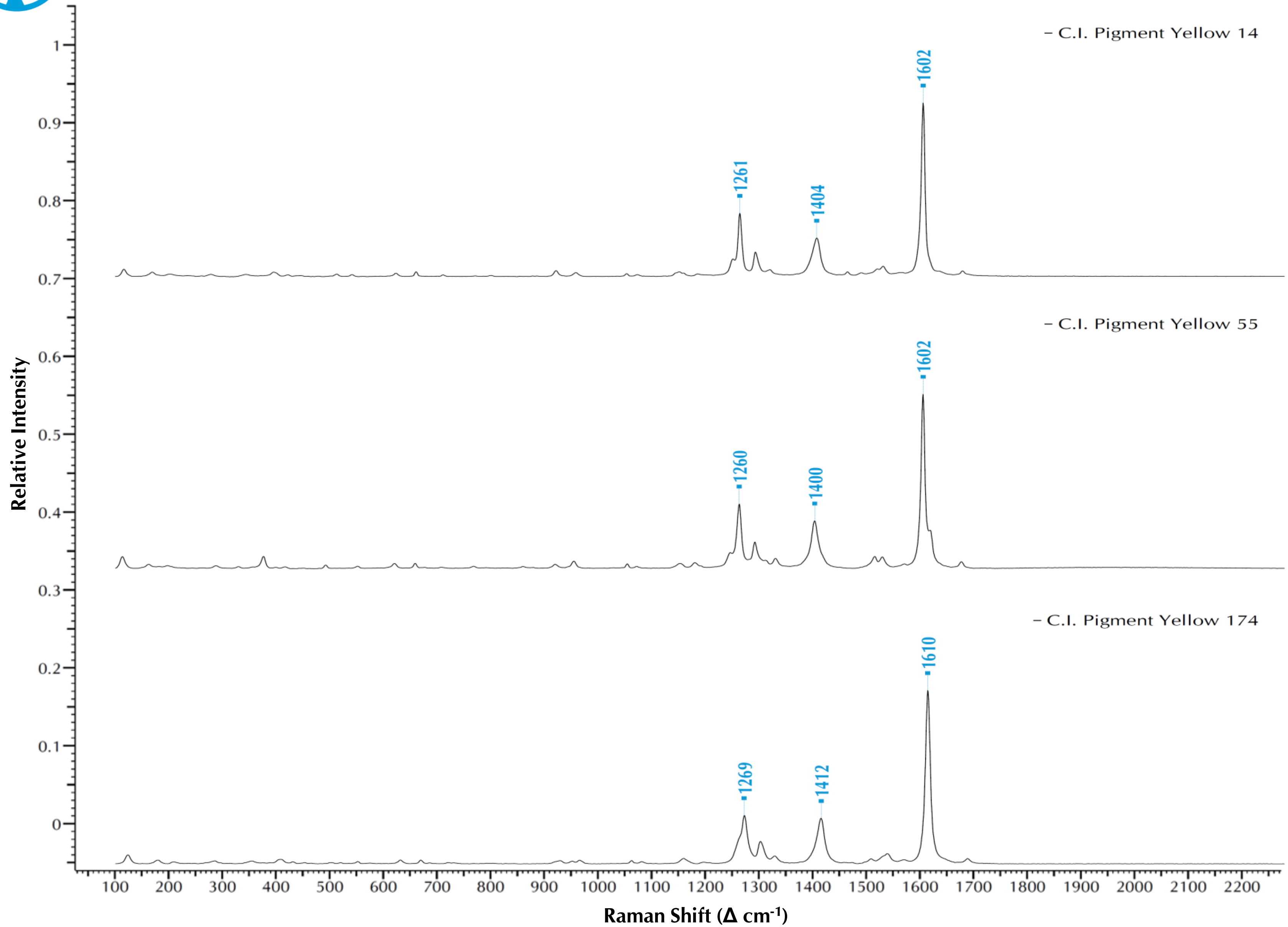
– C.I. Pigment Yellow 83
1599
1255
1403
– C.I. Pigment Yellow 152
1606
1258
1272
1410
– C.I. Pigment Yellow 170
1601
1259
1401
Relative Intensity
Raman Shift (Δ cm⁻¹)

Diarylides



– C.I. Pigment Yellow 17
1603
1402
1256
1272
– C.I. Pigment Yellow 81
1597
1400
1244
1260
– C.I. Pigment Yellow 188
1610
1268
1412
Relative Intensity
Raman Shift (Δ cm-1)

Diarylides


- C.I. Pigment Yellow 14
1602
1261
1404
- C.I. Pigment Yellow 55
1602
1260
1400
- C.I. Pigment Yellow 174
1610
1269
1412
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

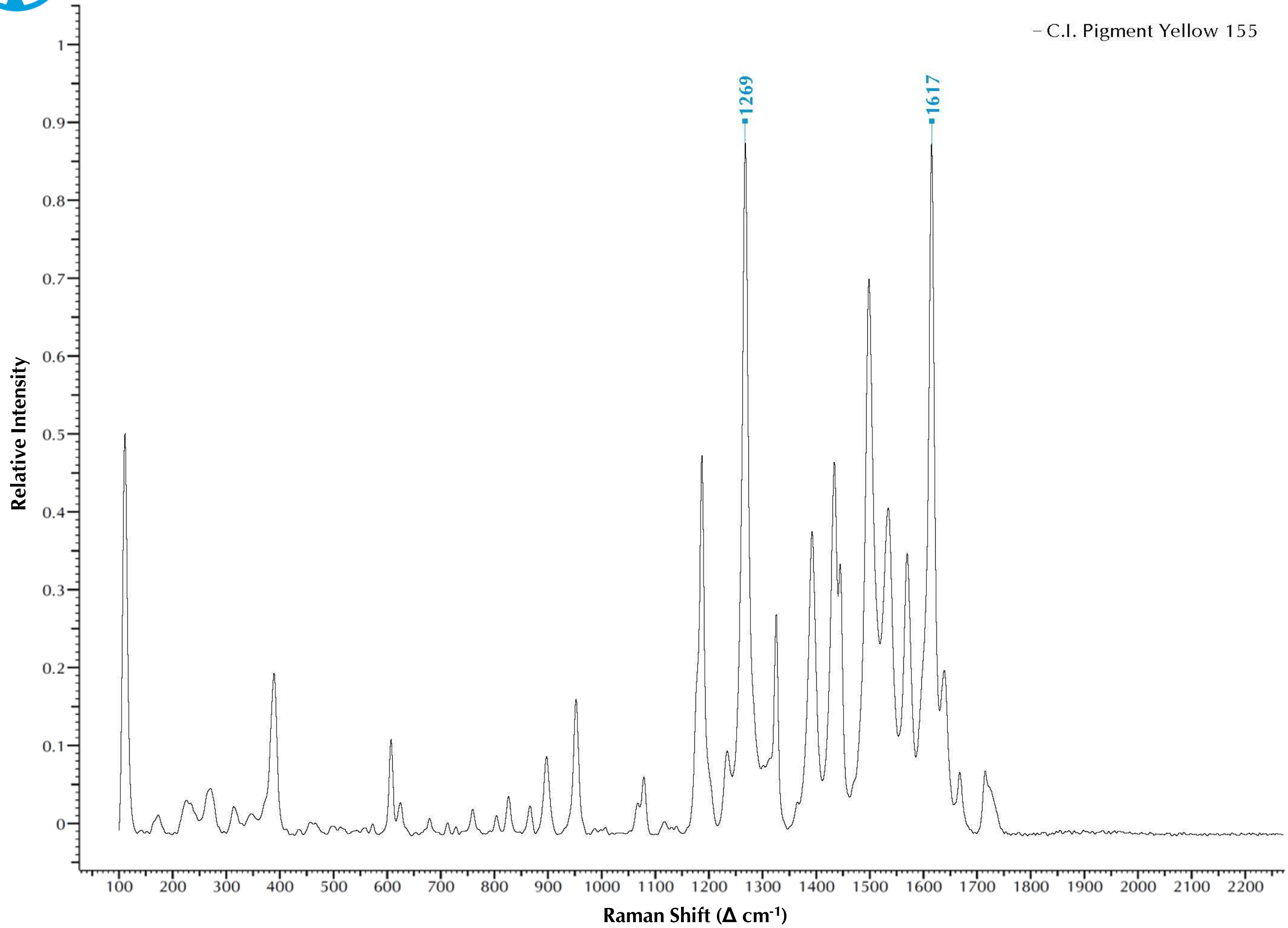
Bisacetoacetarylide

Bisacetoacetarylide

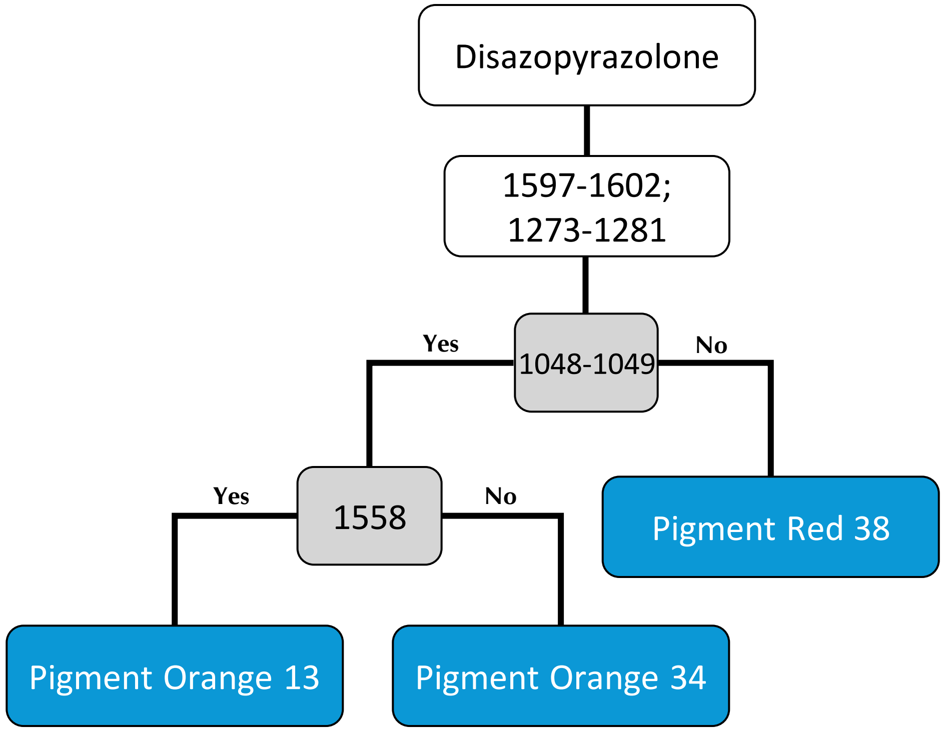
1617;
1269

Pigment Yellow 155

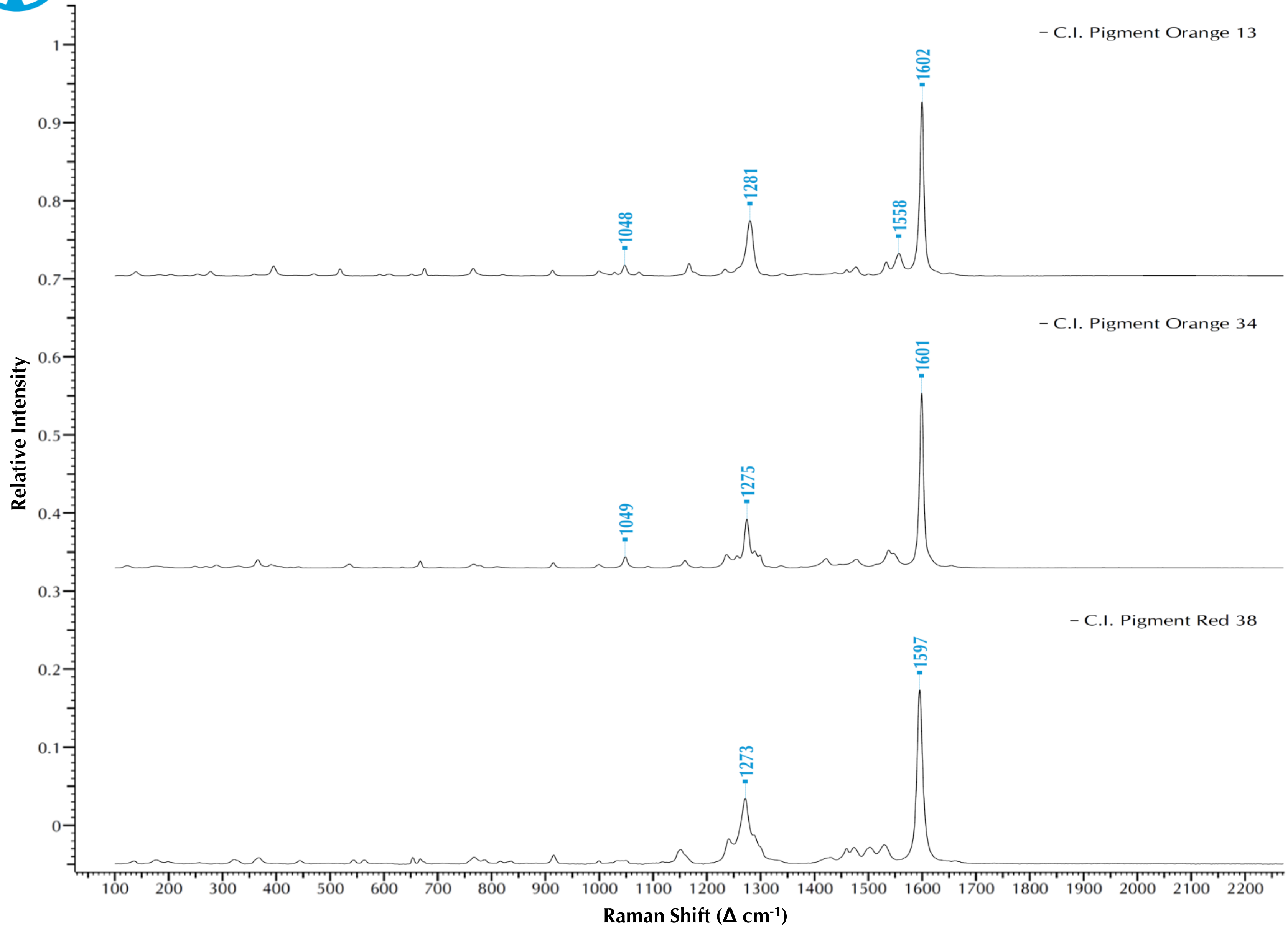
Bisacetoacetarylide



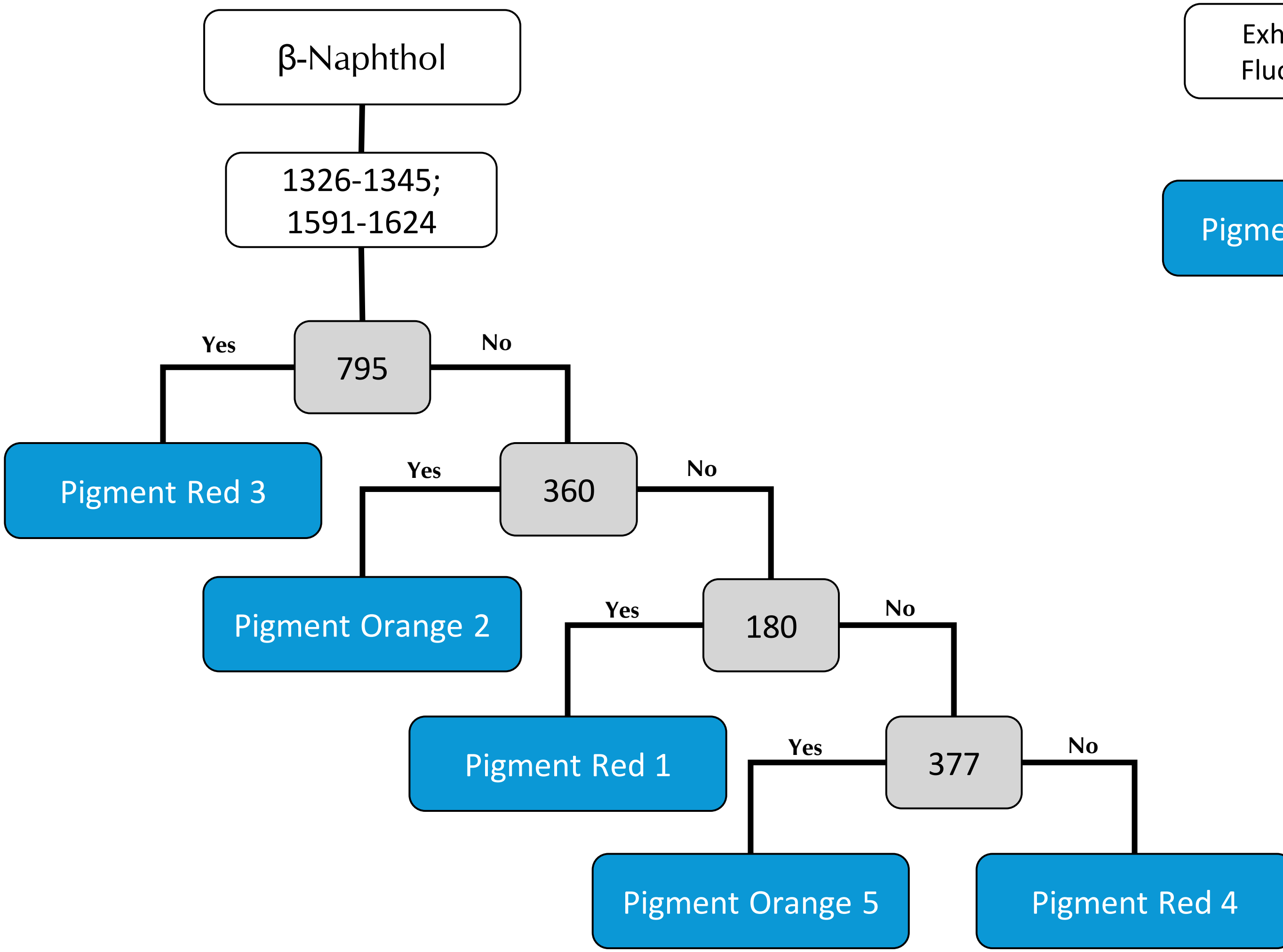
Disazopyrazolone

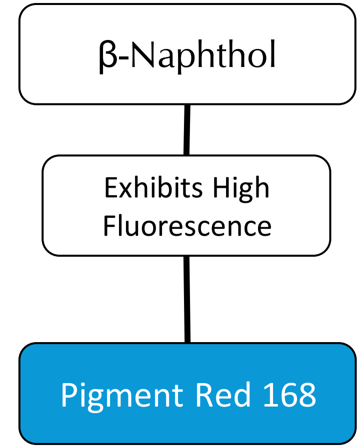


Disazopyrazolone

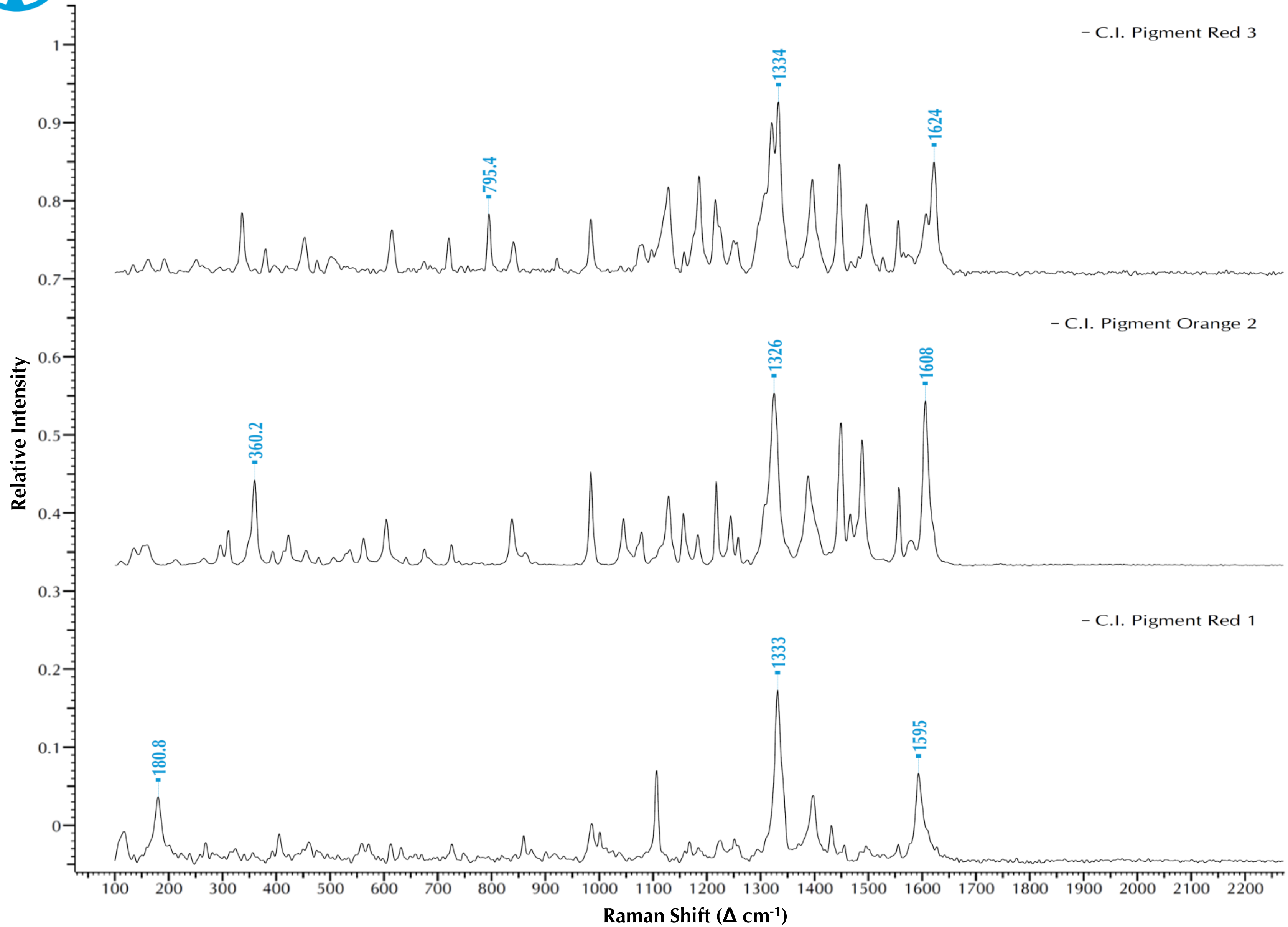


β-Naphthol


β-Naphthol
1326-1345; 1591-1624
795
Yes
No
Pigment Red 3
360
Yes
No
Pigment Orange 2
180
Yes
No
Pigment Red 1
377
Yes
No
Pigment Orange 5
Pigment Red 4

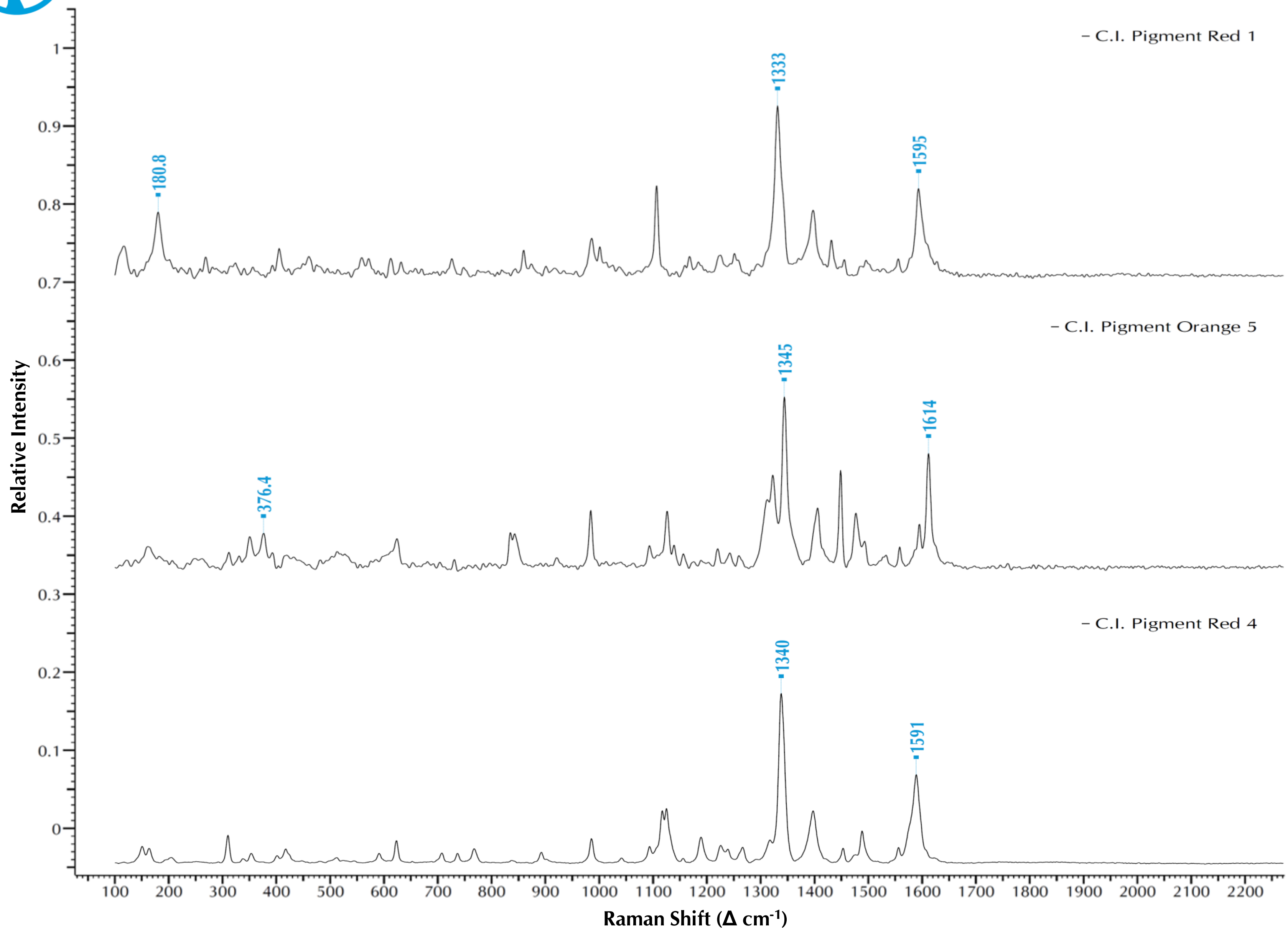

β-Naphthol
Exhibits High Fluorescence
Pigment Red 168

β-Naphthol



– C.I. Pigment Red 3
– C.I. Pigment Orange 2
– C.I. Pigment Red 1
795.4
1334
1624
360.2
1326
1608
180.8
1333
1595
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200
Raman Shift (Δ cm-1)

β-Naphthol



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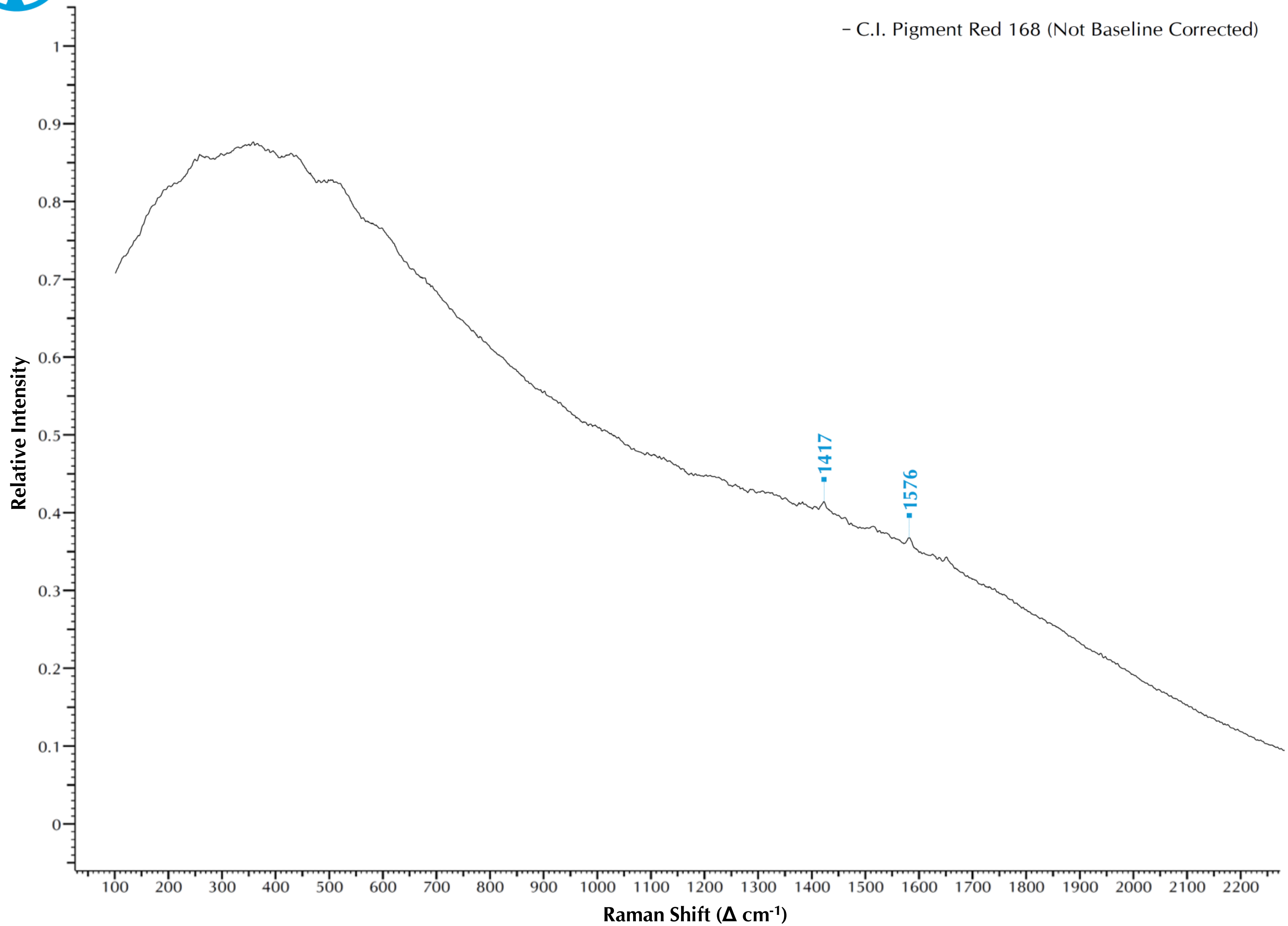
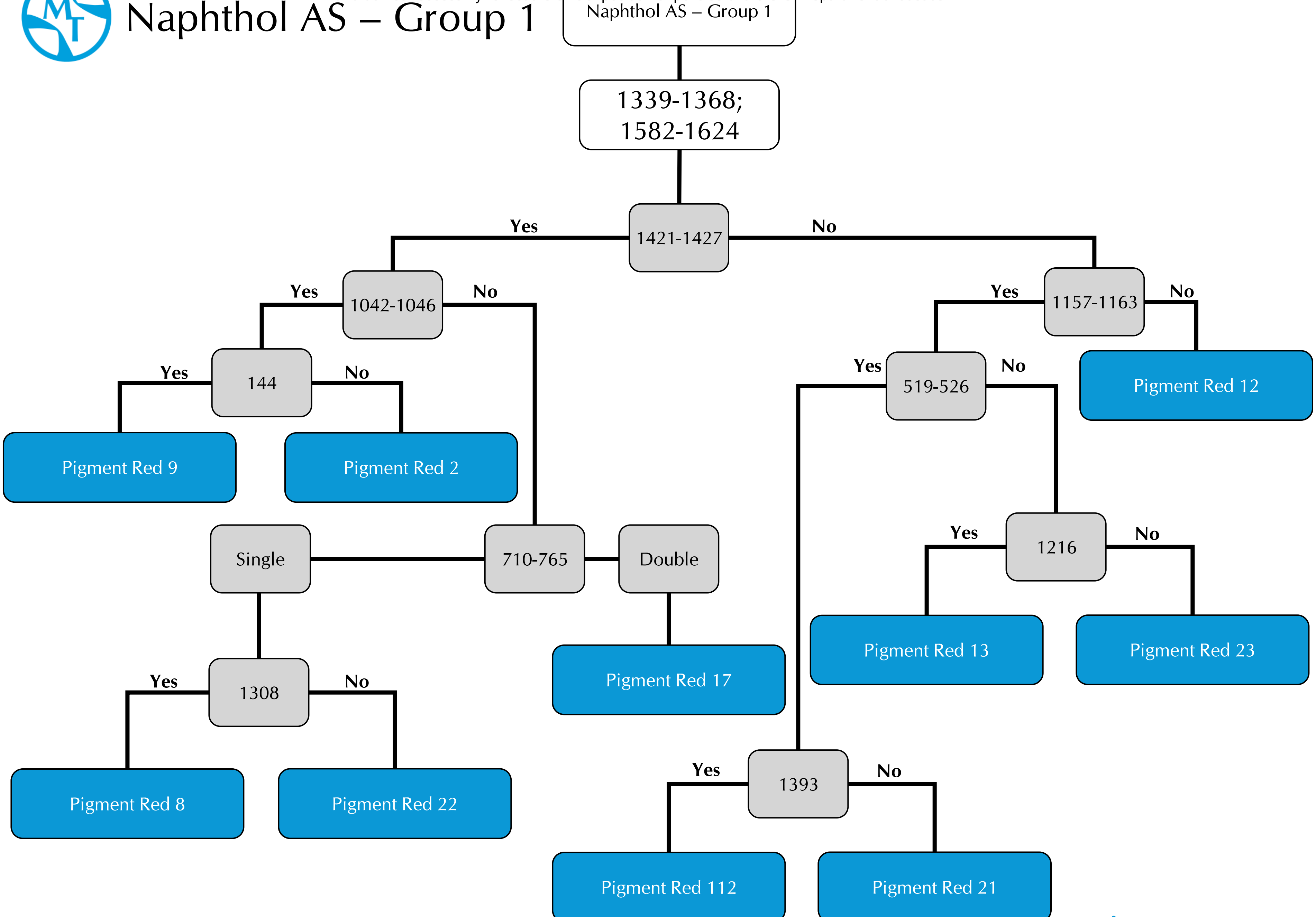
β-Naphthol

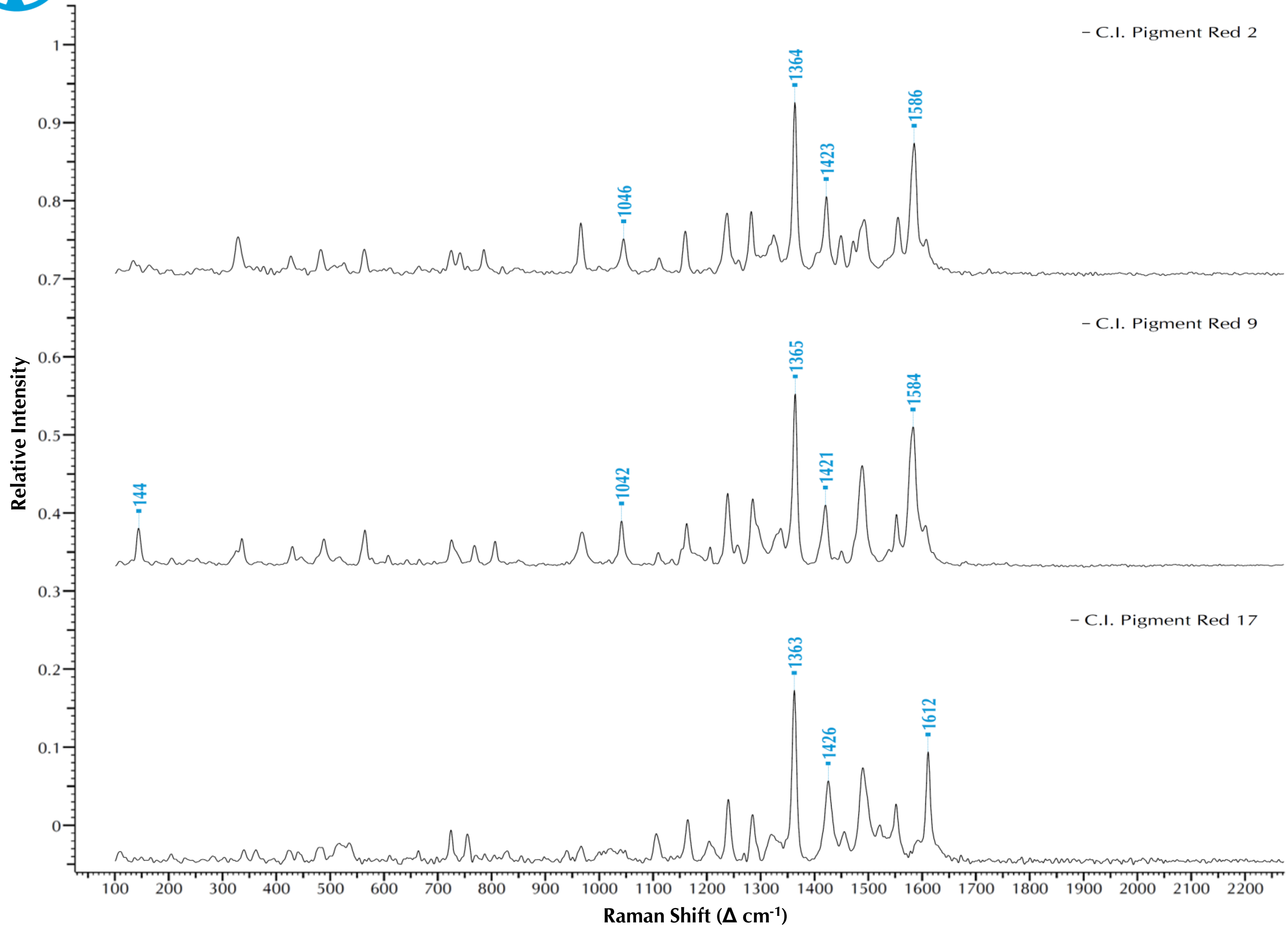

- C.I. Pigment Red 168 (Not Baseline Corrected)
1417
1576
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Naphthol AS – Group 1

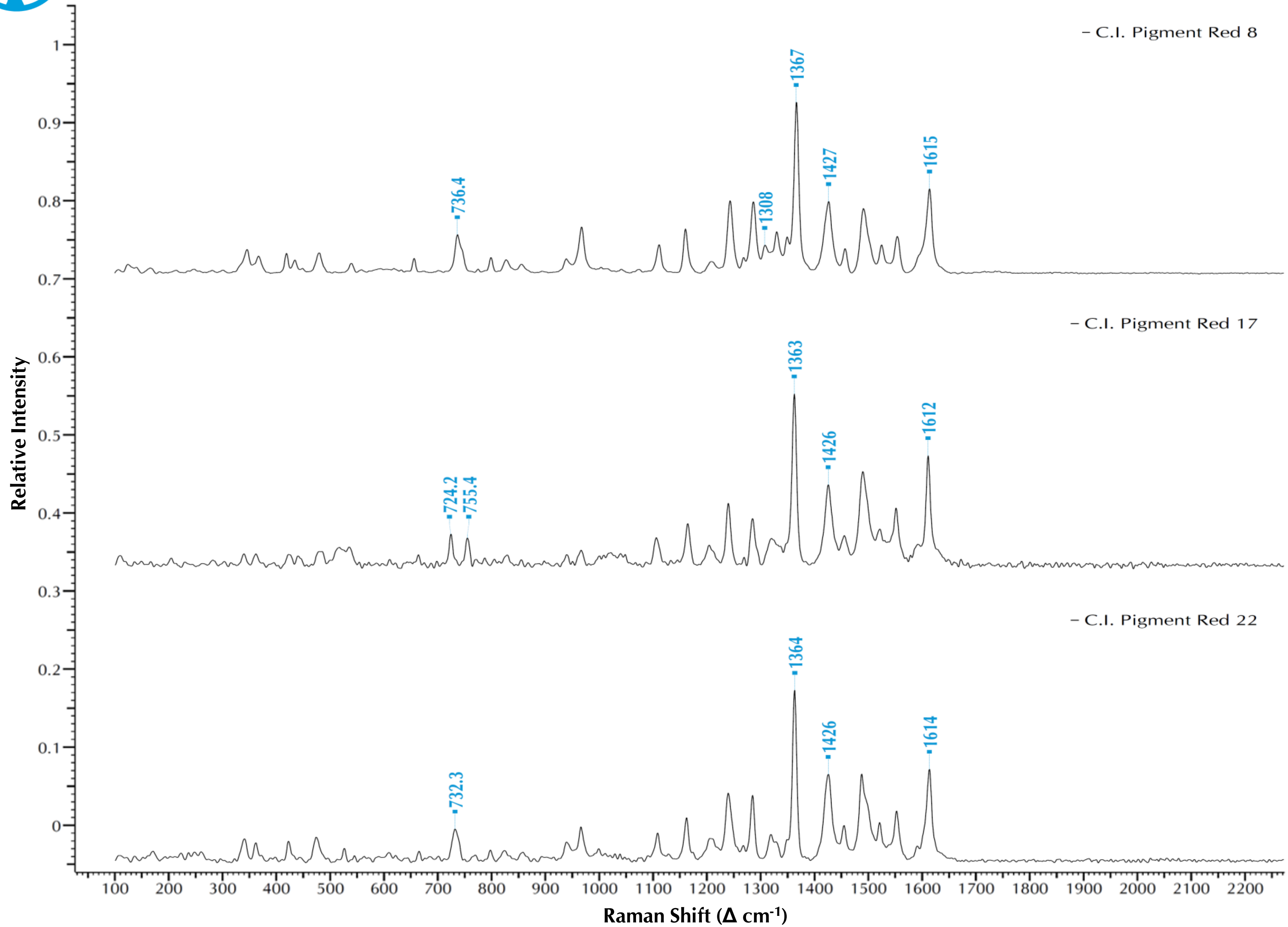


Microtrace LLC

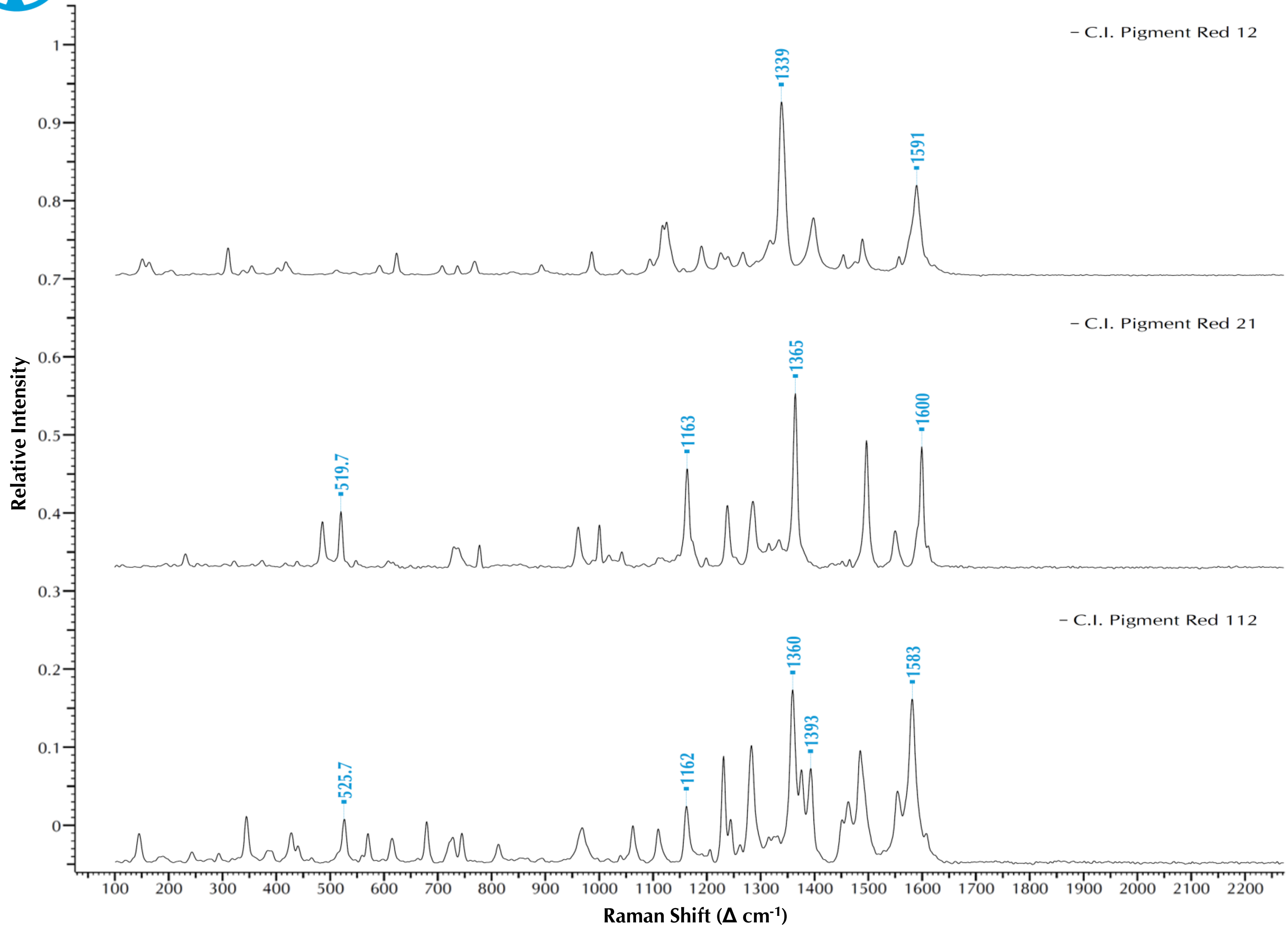
Naphthol AS – Group 1



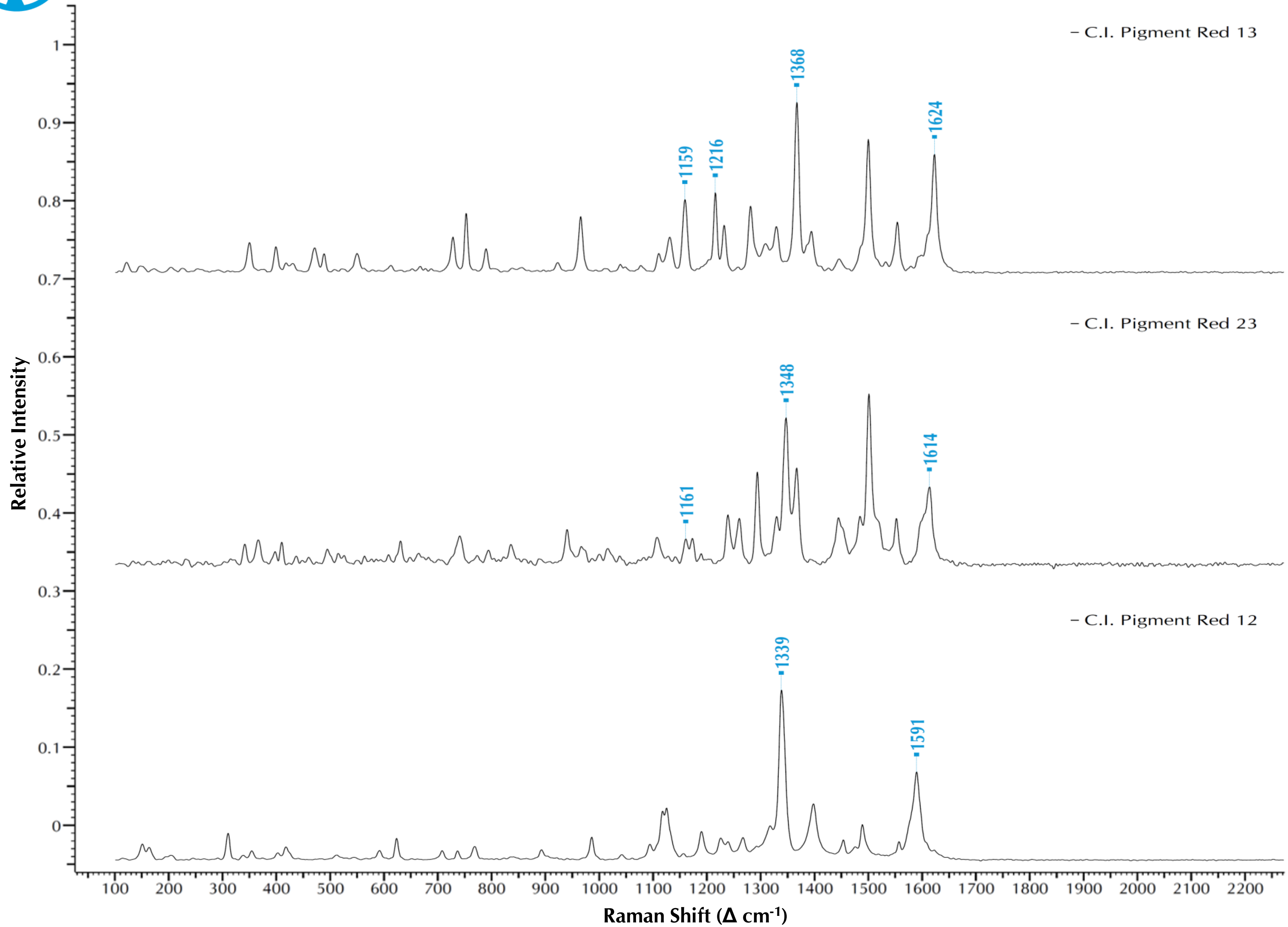
Naphthol AS – Group 1



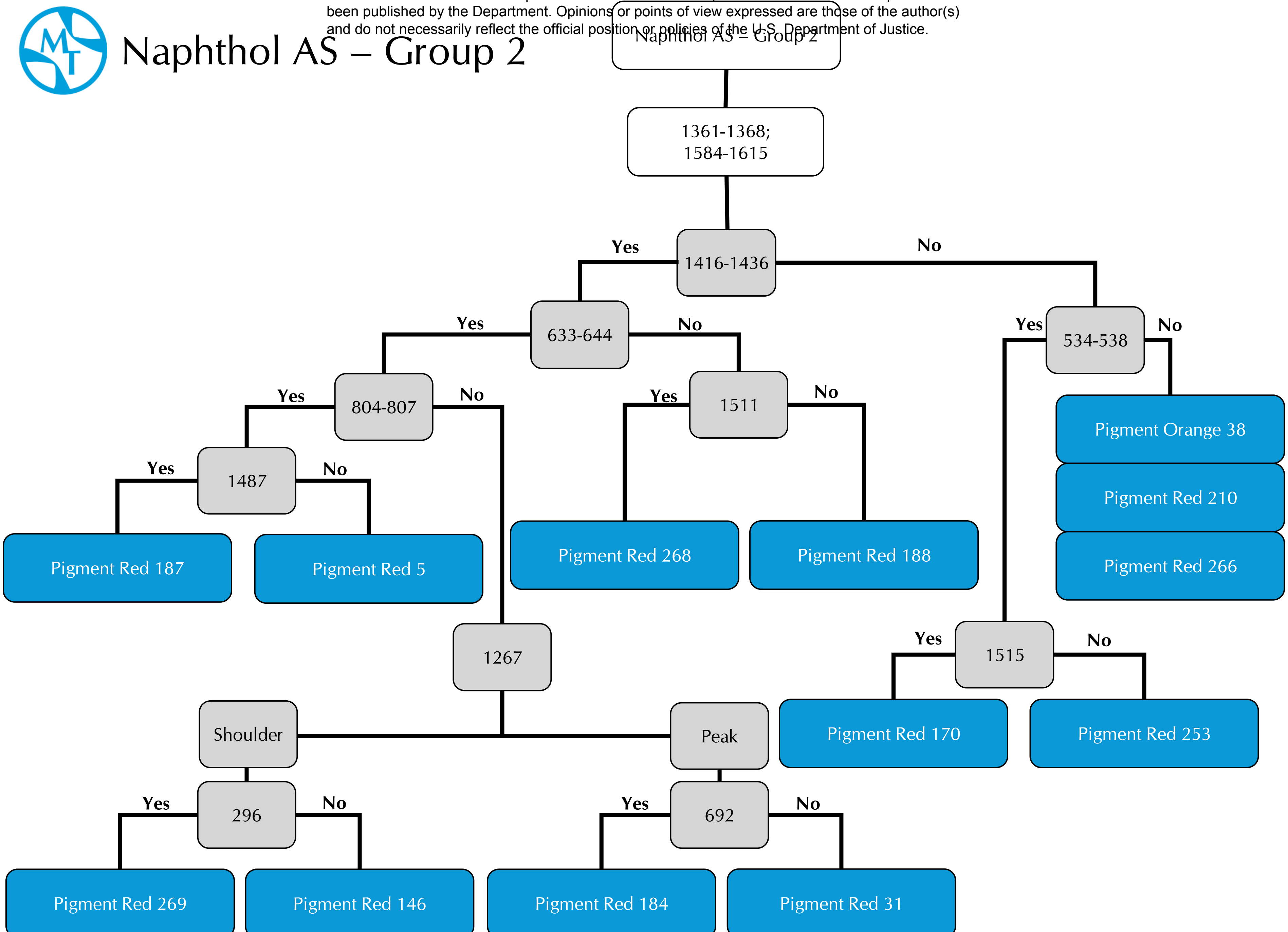
Naphthol AS – Group 1



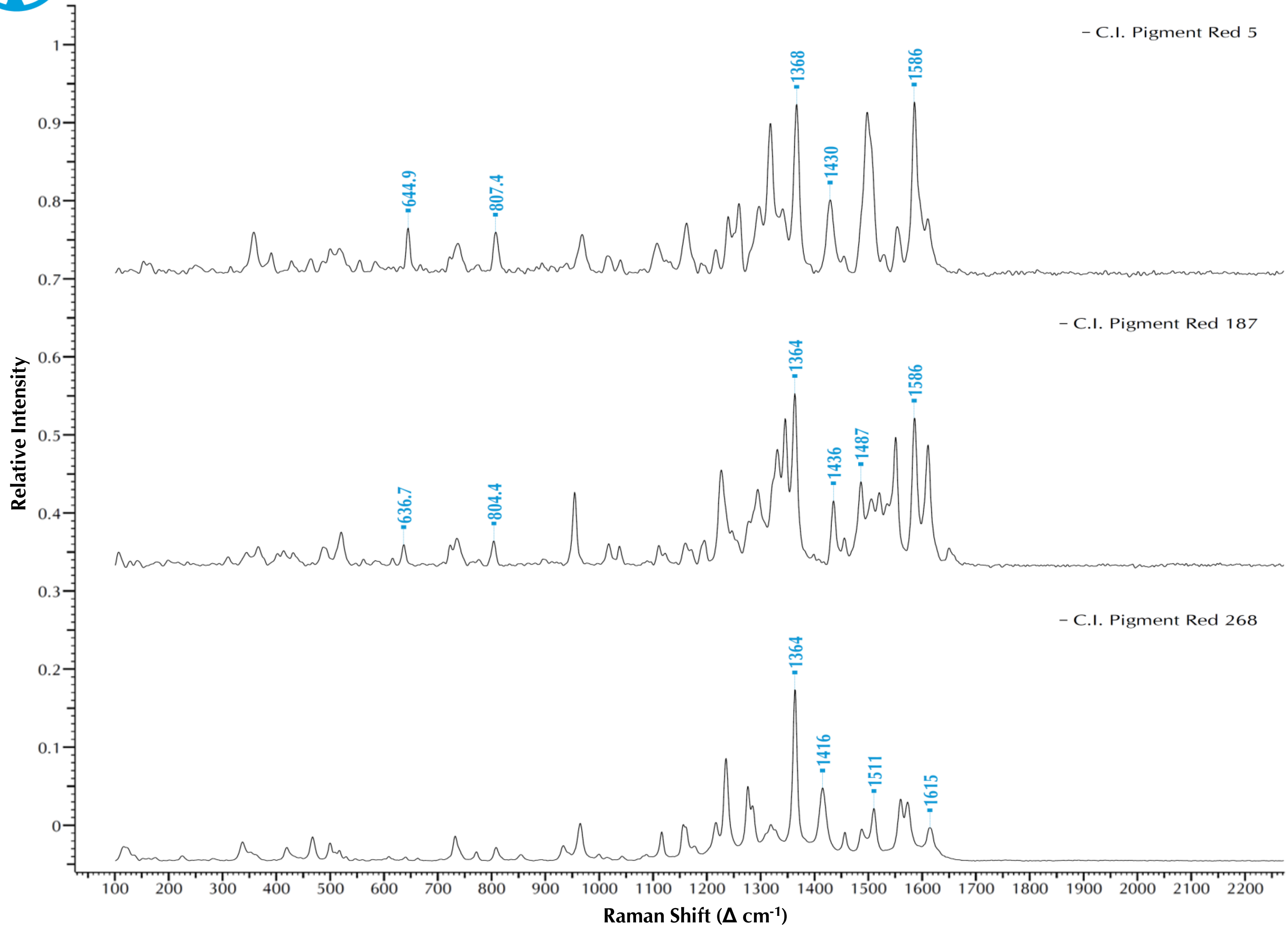
Naphthol AS – Group 1



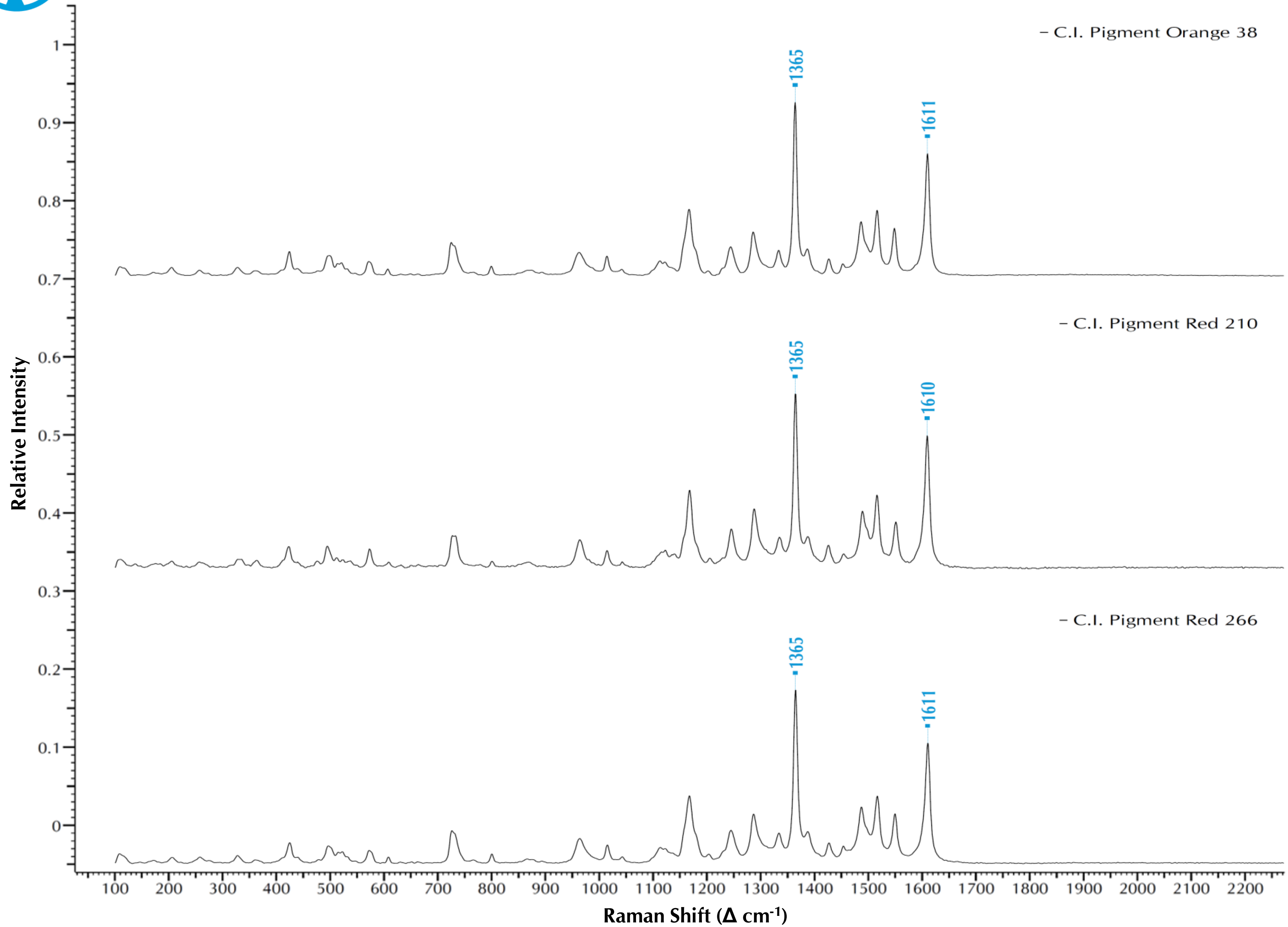
Naphthol AS – Group 2



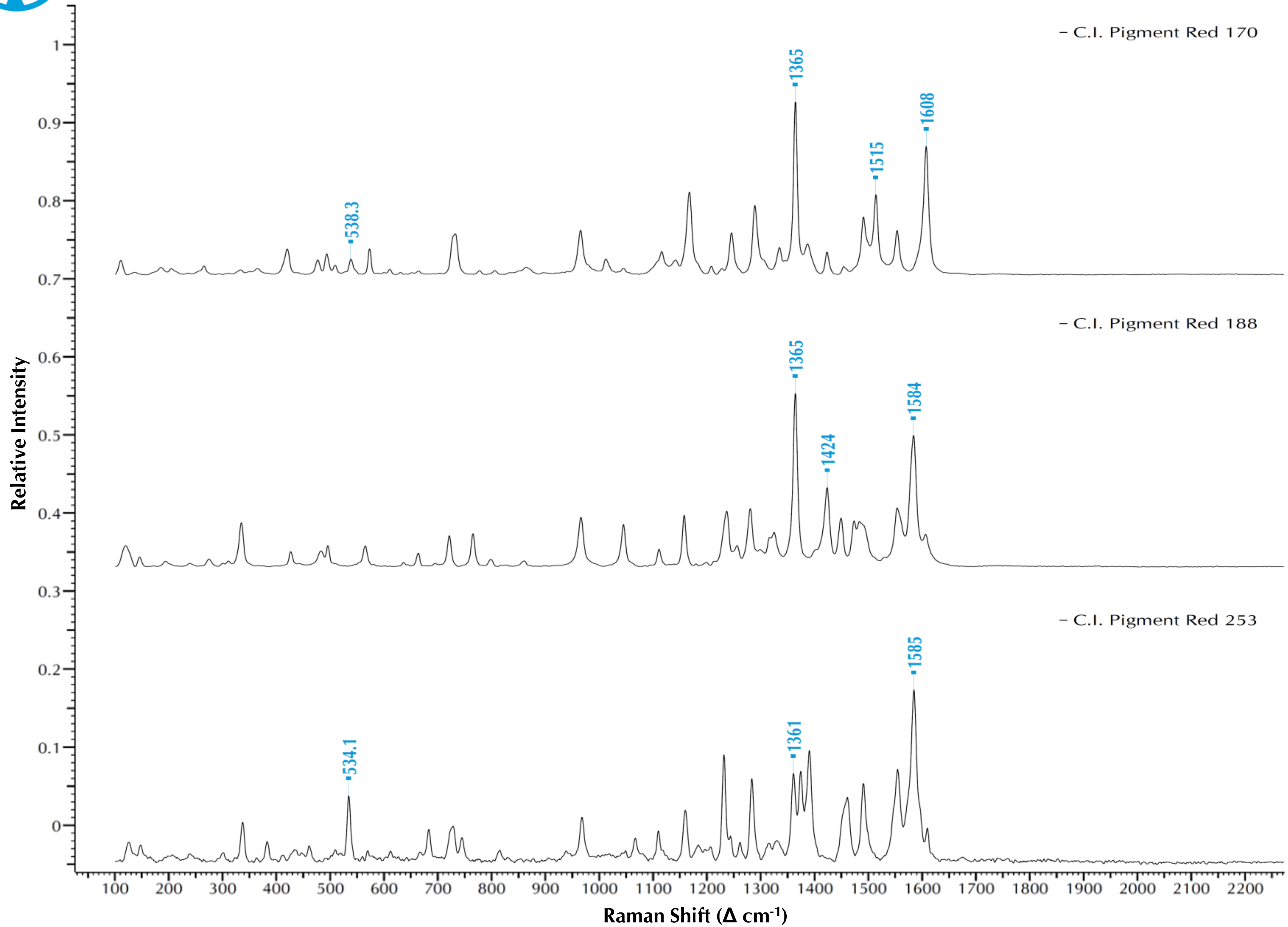
Naphthol AS – Group 2



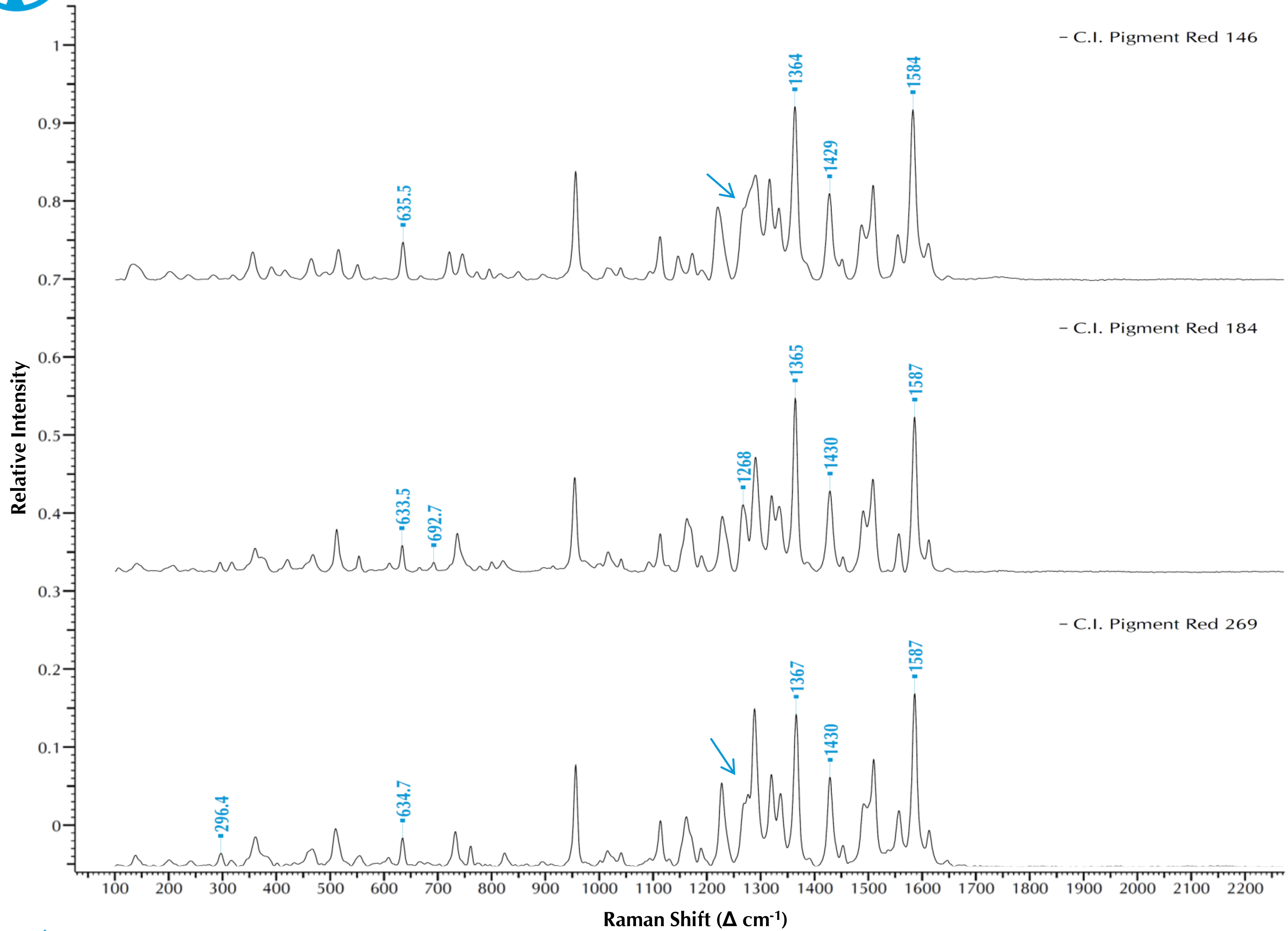
Naphthol AS – Group 2



Naphthol AS – Group 2

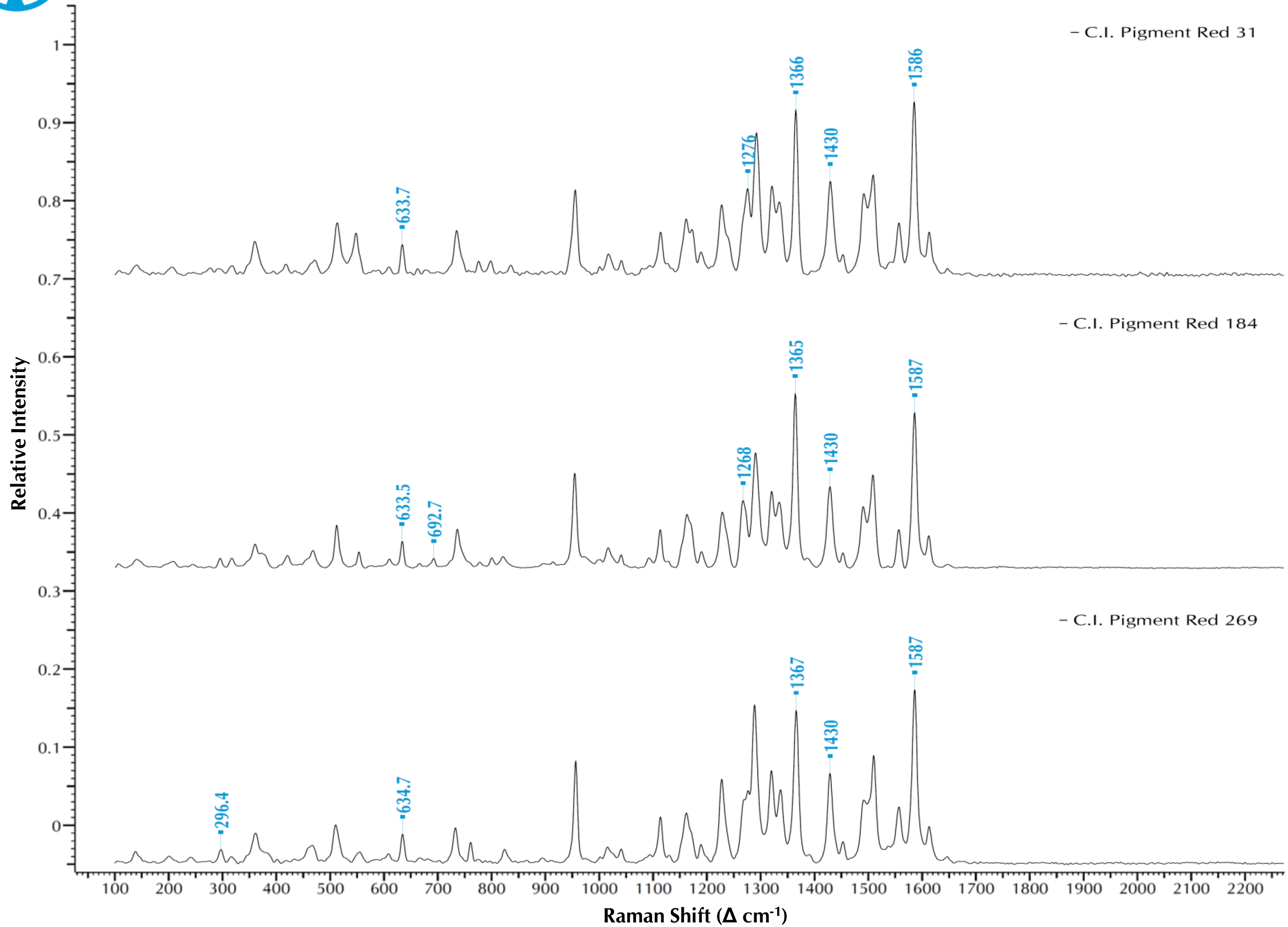


Naphthol AS – Group 2

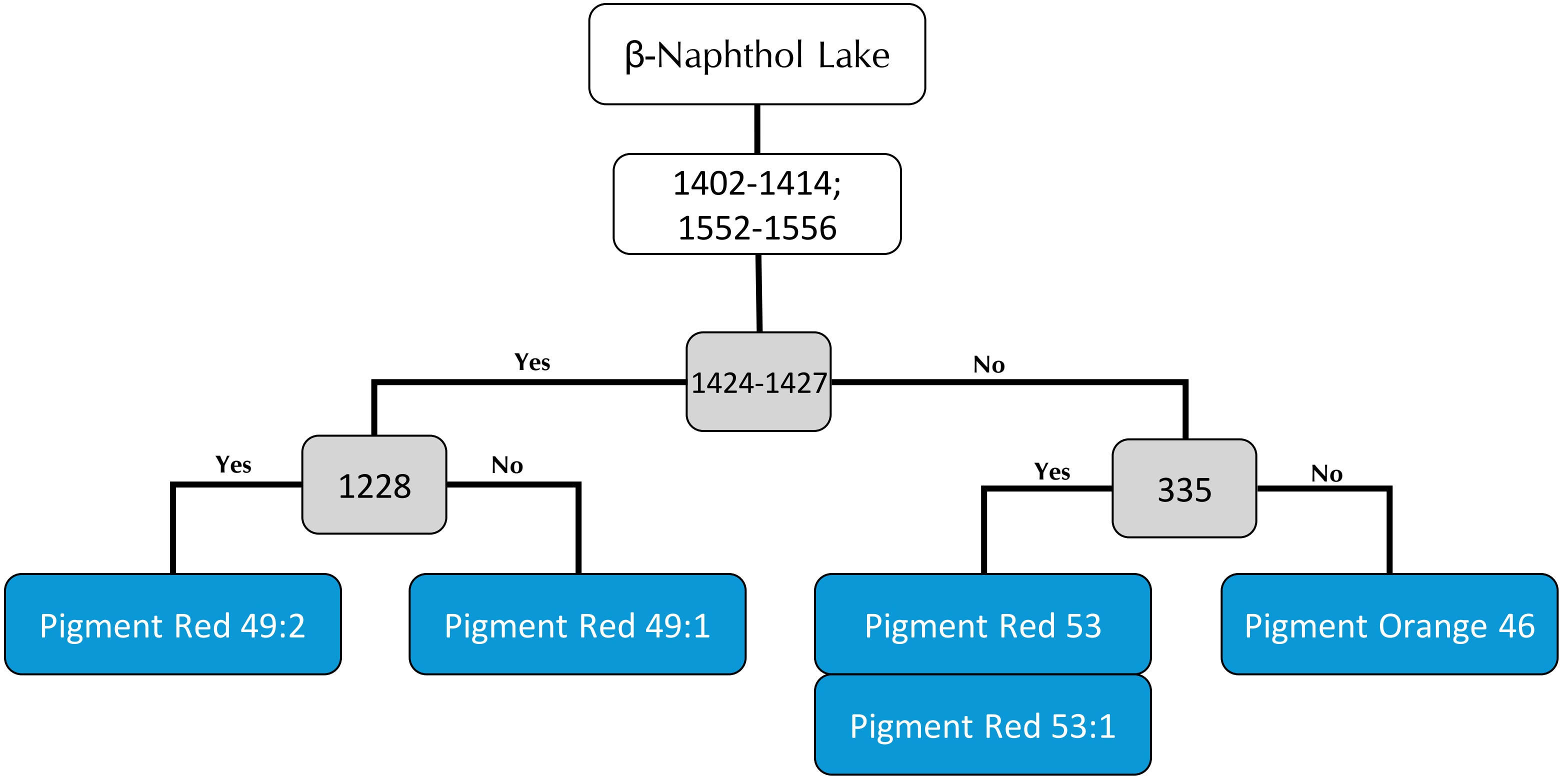


Arrow indicates shoulder – distinguishing feature from flow chart

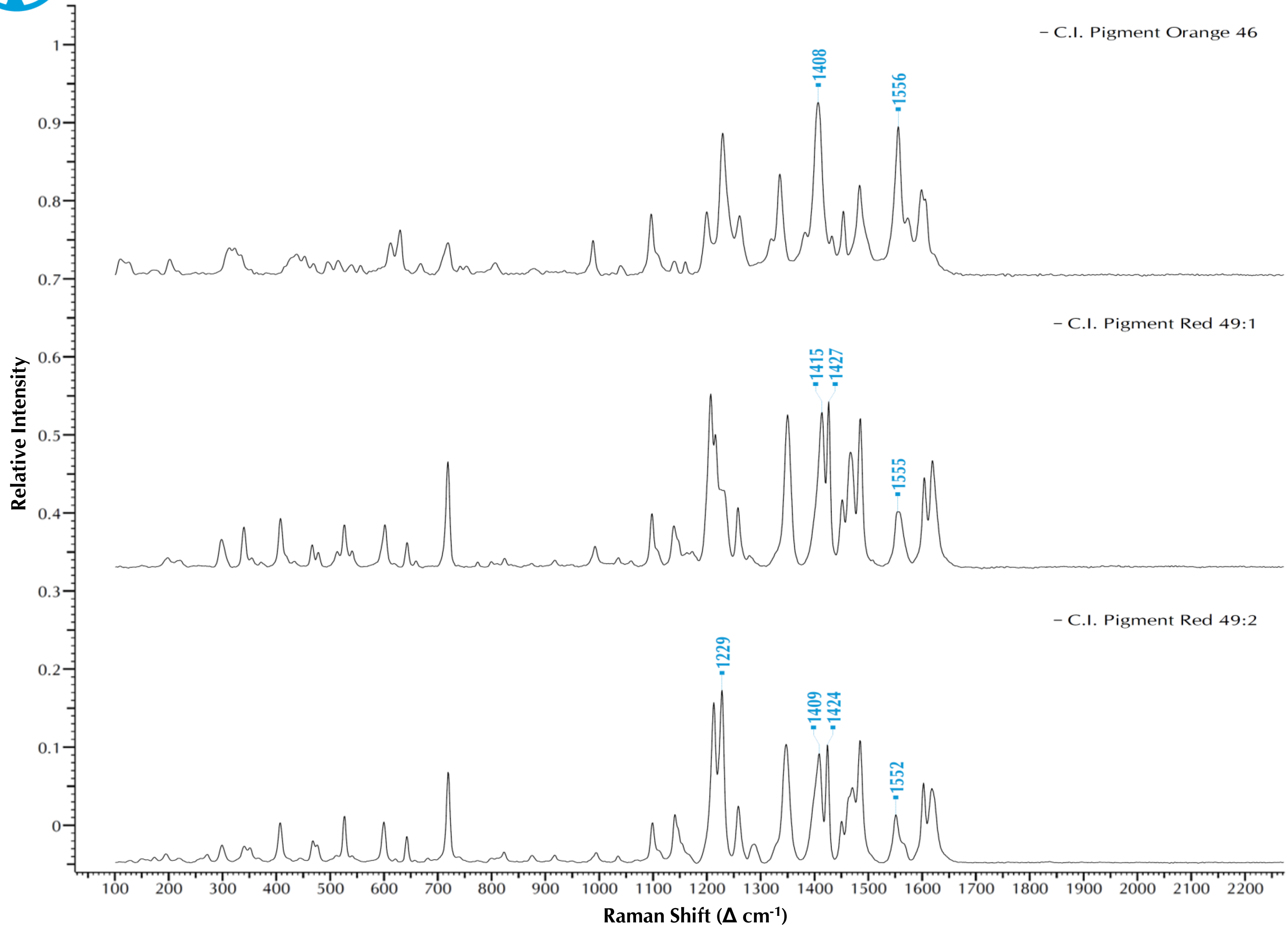
Naphthol AS – Group 2



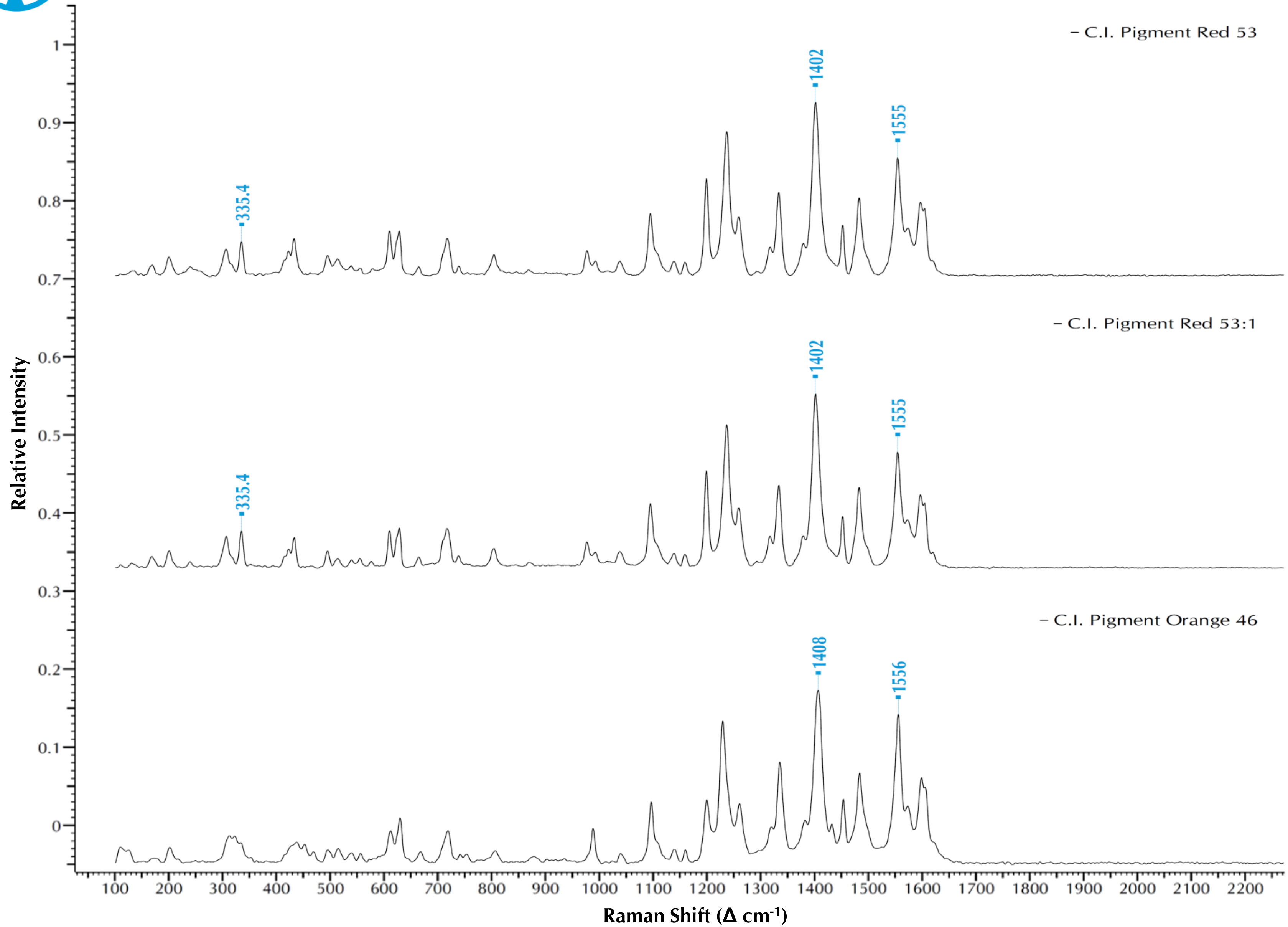
β-Naphthol Lake

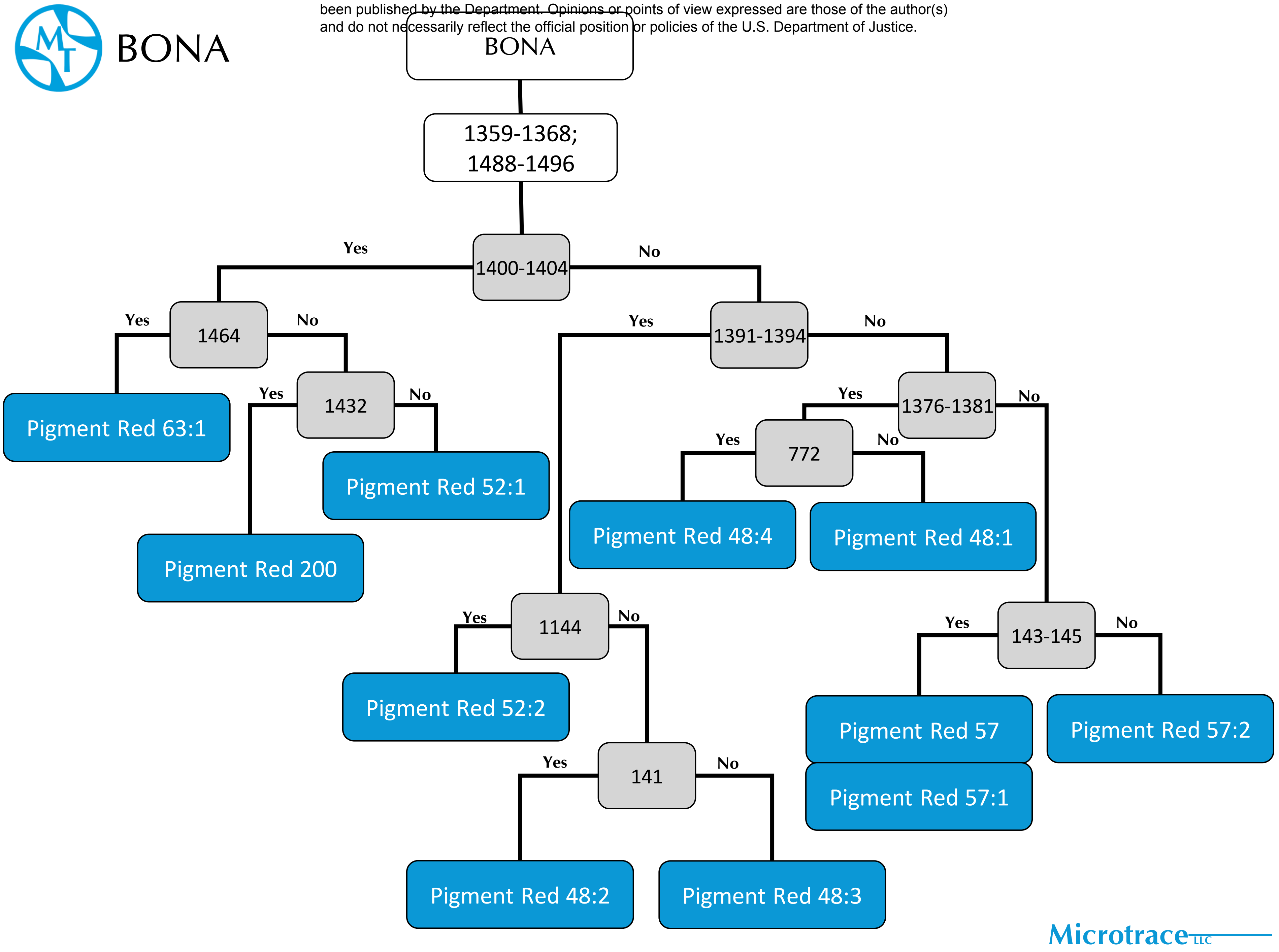


β-Naphthol Lake

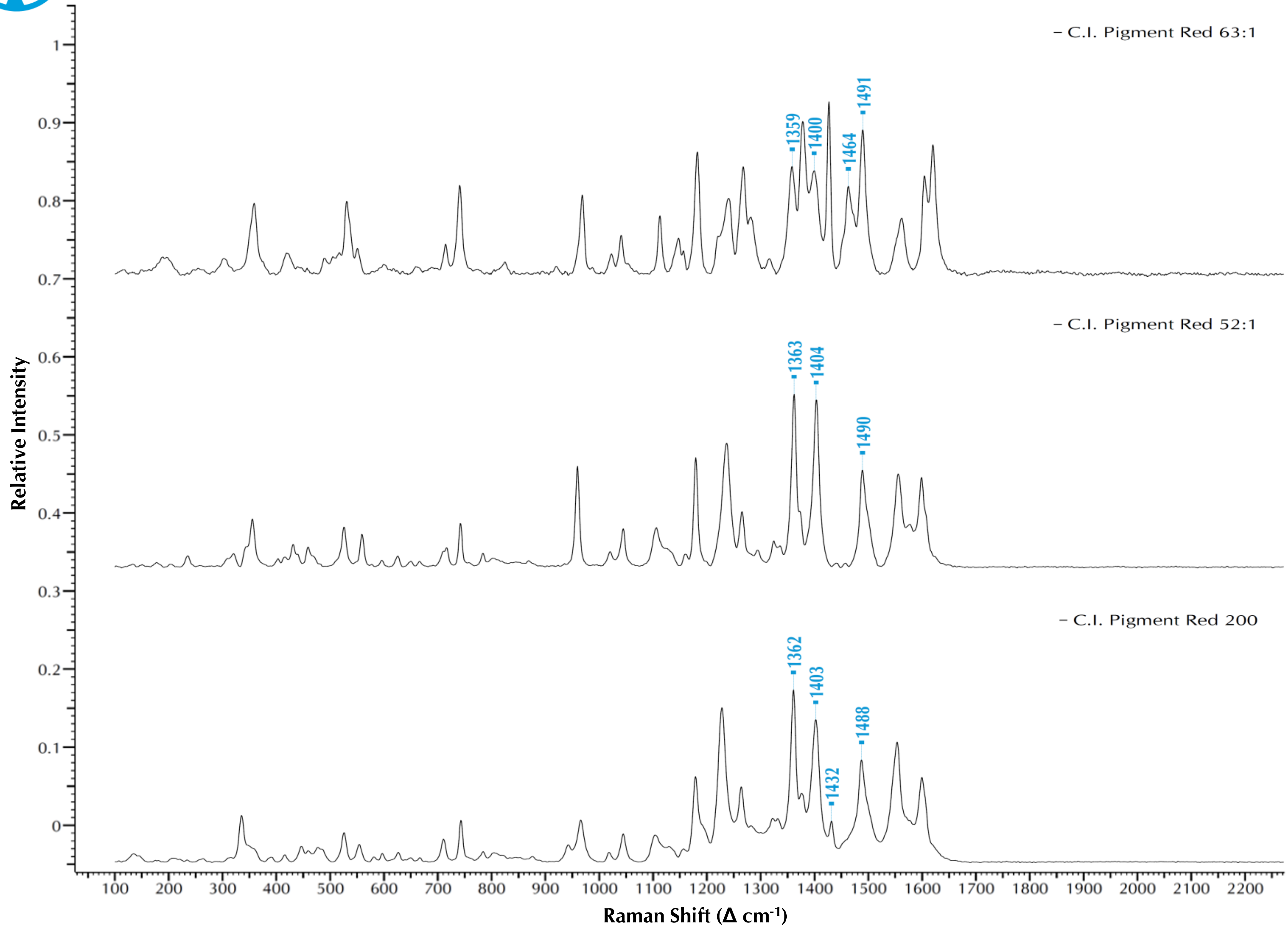


β-Naphthol Lake



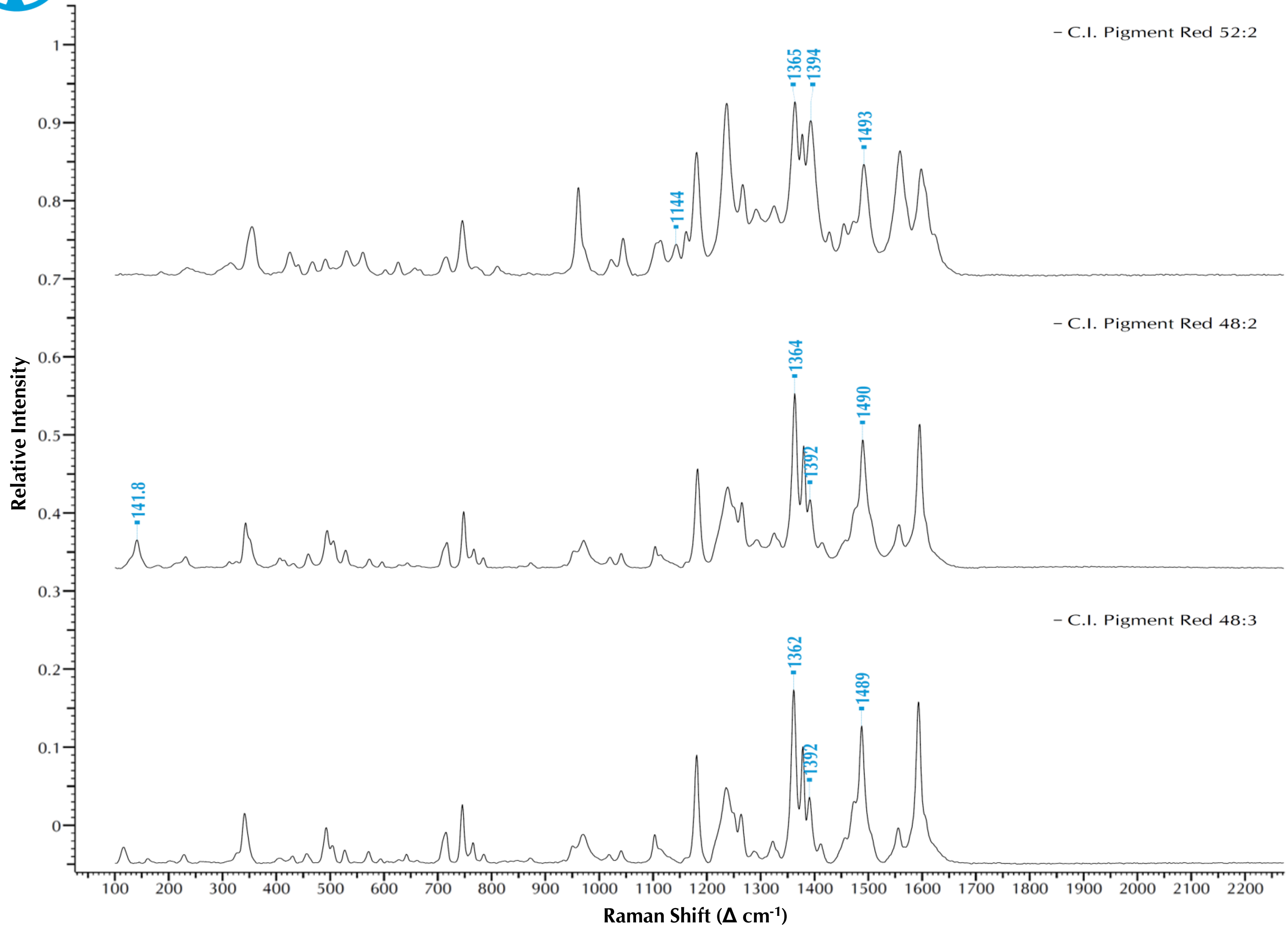

BONA
BONA
1359-1368; 1488-1496
1400-1404
Yes
No
1464
Yes
No
Pigment Red 63:1
1432
Yes
No
Pigment Red 52:1
Pigment Red 200
1391-1394
Yes
No
1376-1381
Yes
No
772
Yes
No
Pigment Red 48:4
Pigment Red 48:1
1144
Yes
No
Pigment Red 52:2
141
Yes
No
Pigment Red 48:2
Pigment Red 48:3
143-145
Yes
No
Pigment Red 57
Pigment Red 57:1
Pigment Red 57:2
Microtrace LLC

BONA



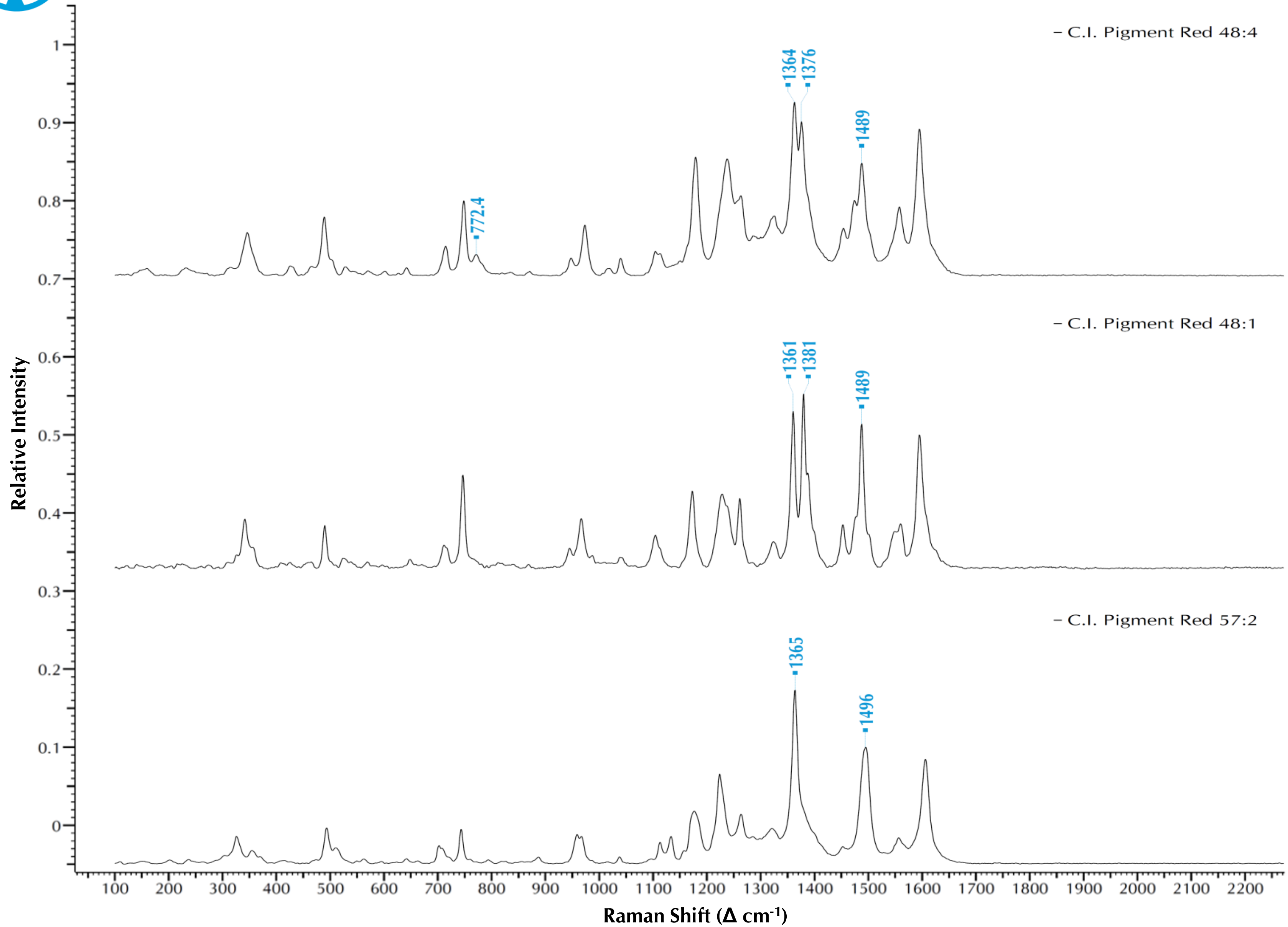
Microtrace LLC

BONA



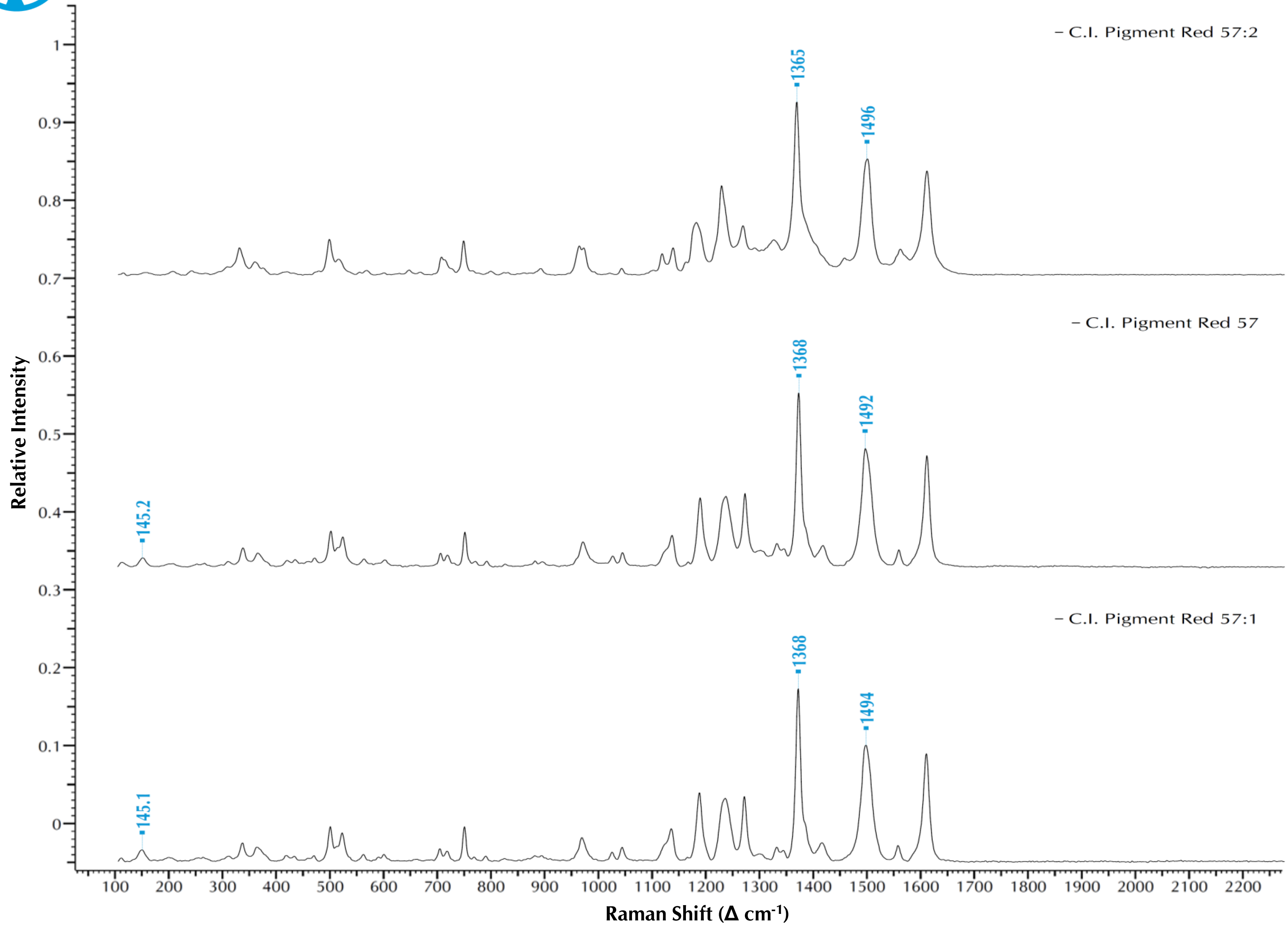
Microtrace LLC

BONA



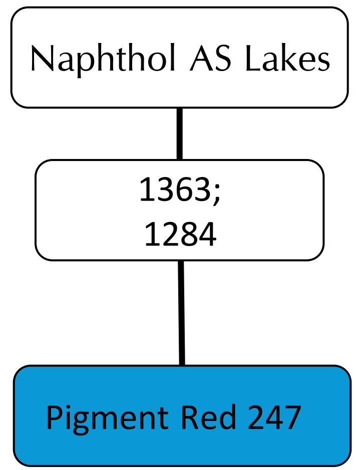
Microtrace LLC

BONA

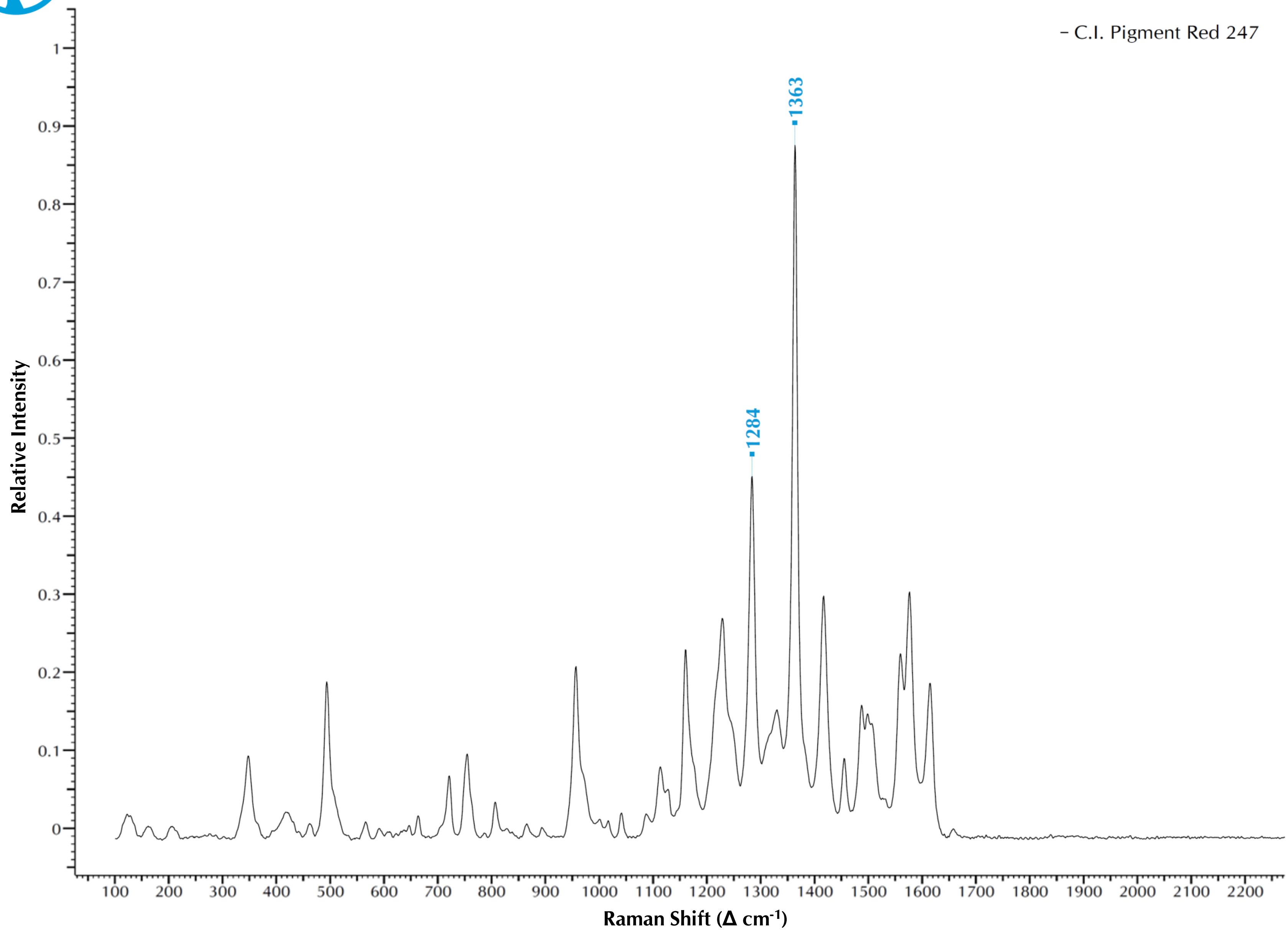


Microtrace LLC

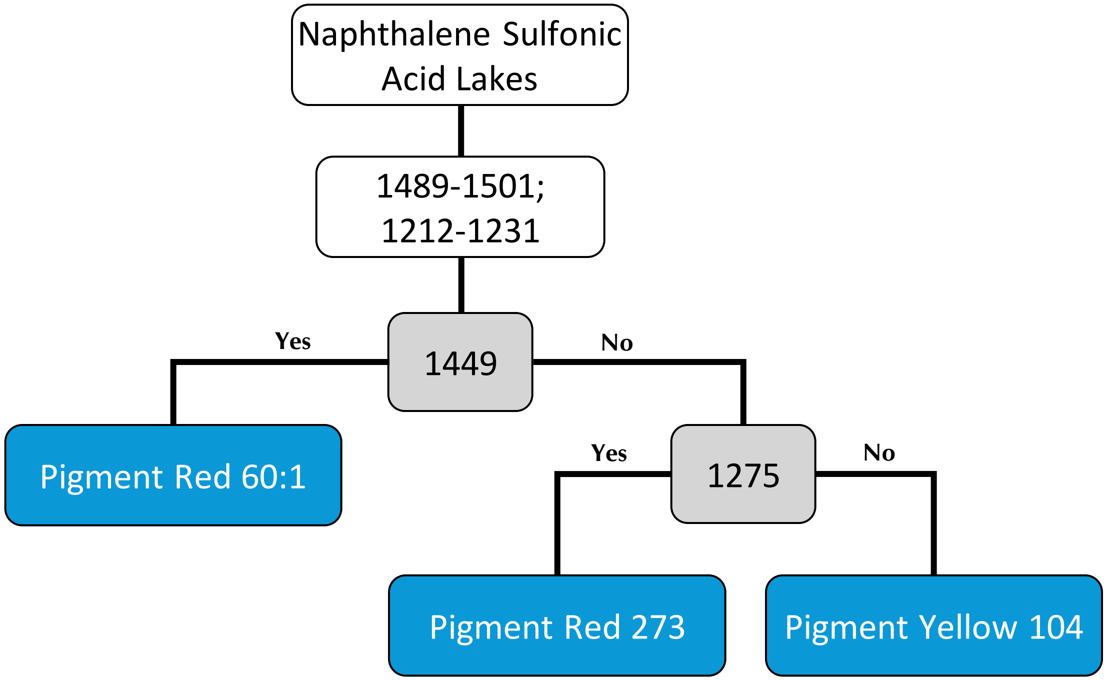
Naphthol AS Lakes



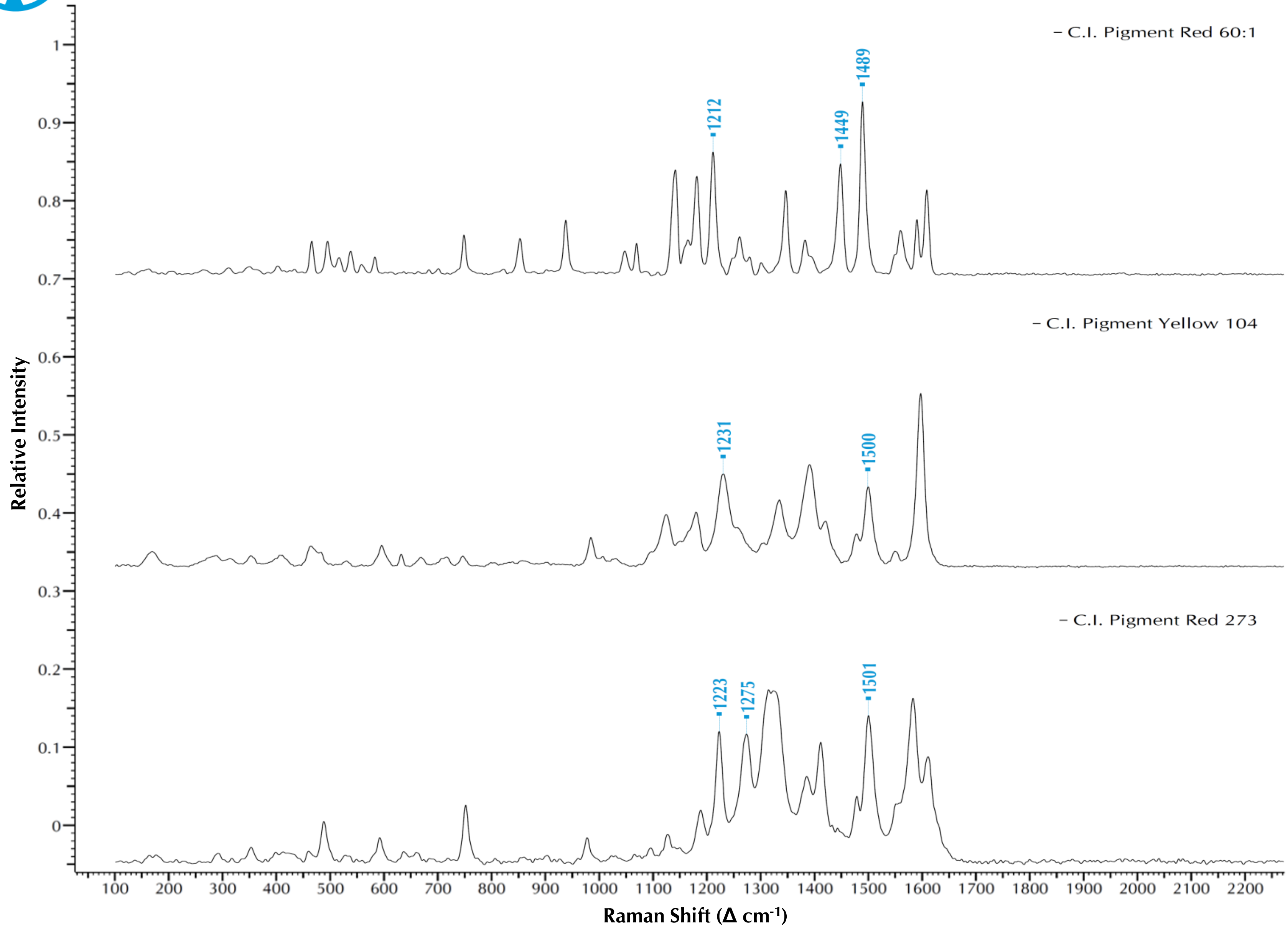
Naphthol AS Lakes



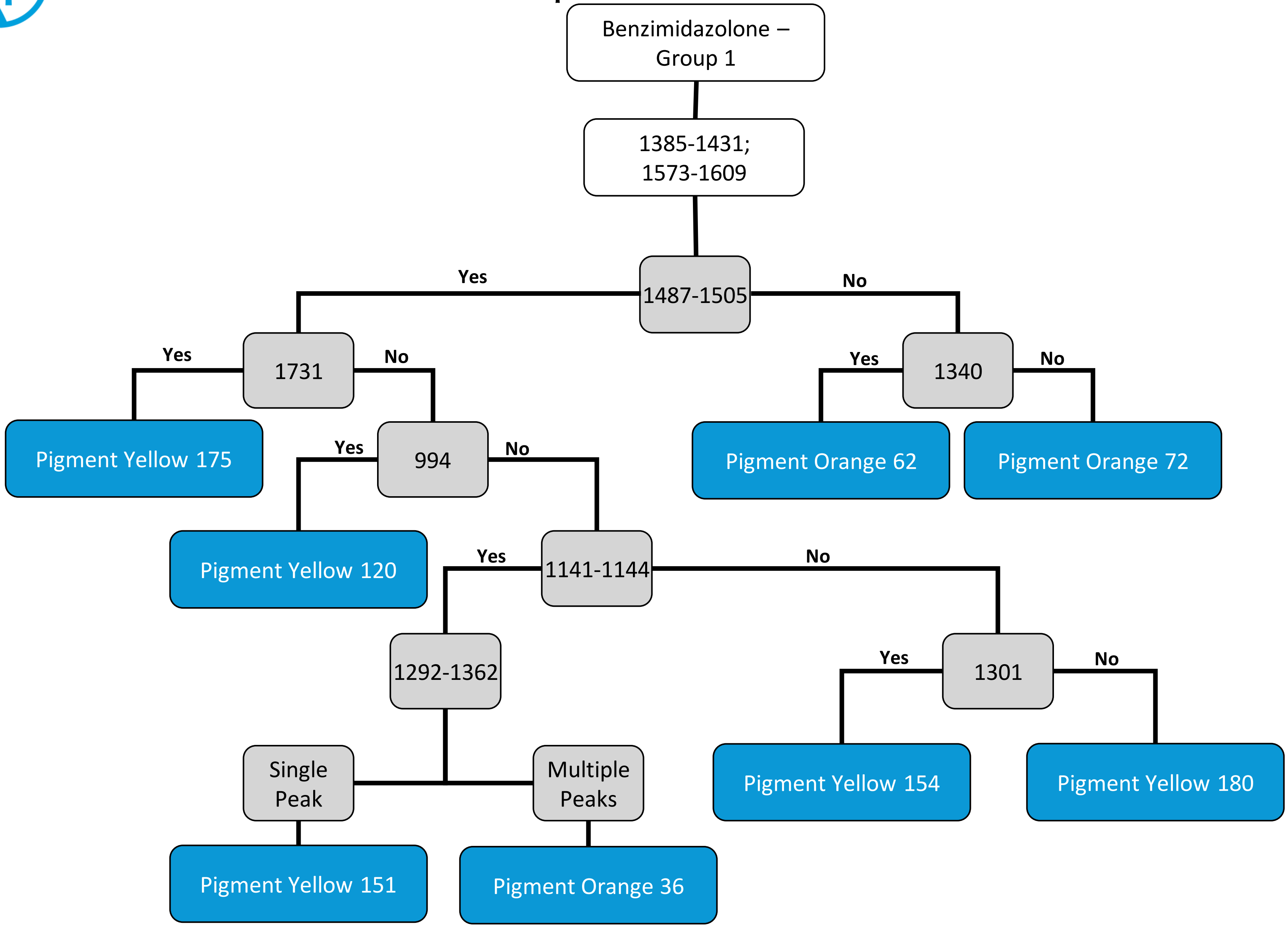
Naphthalene Sulfonic Acid Lakes



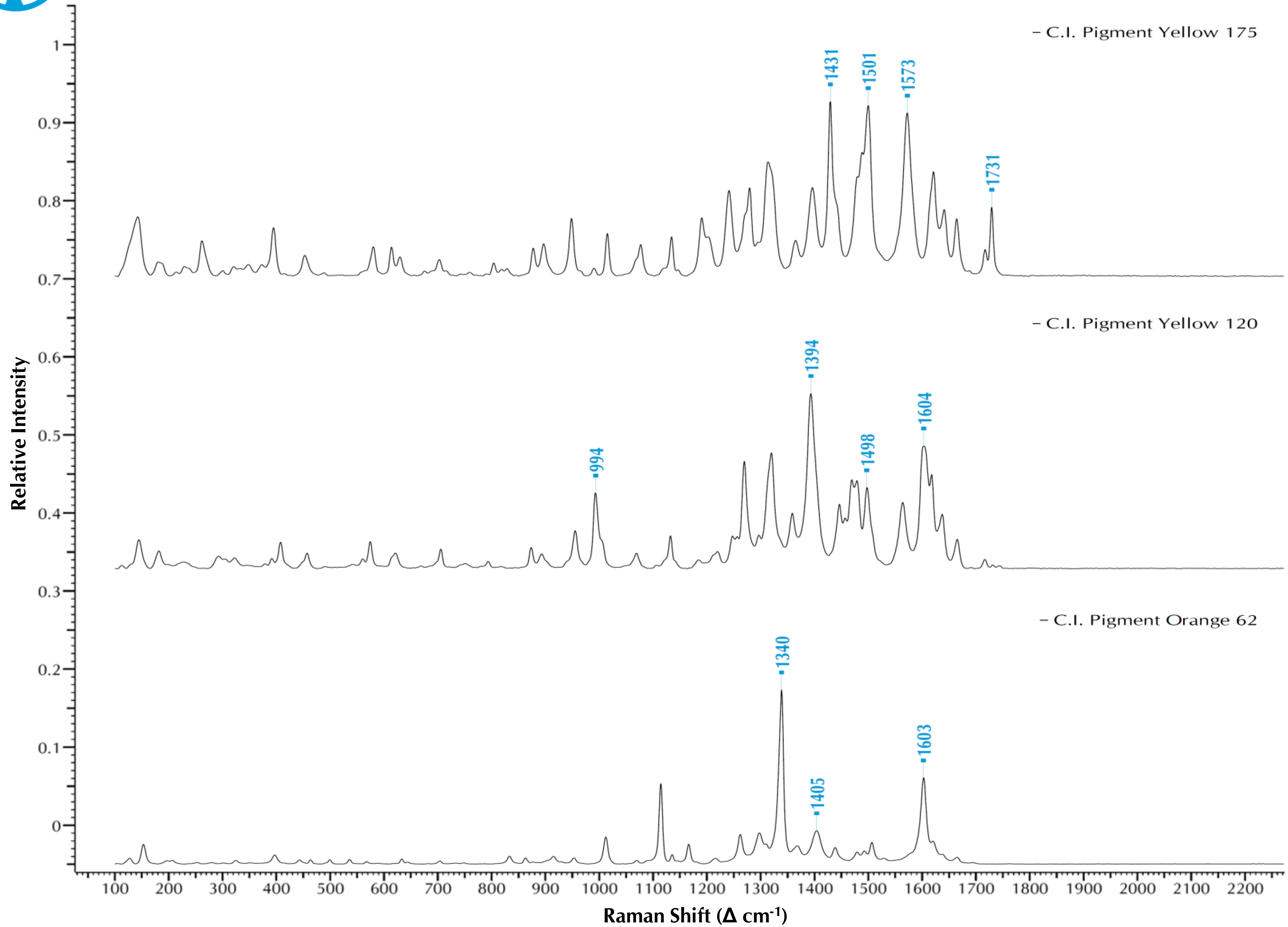
Naphthalene Sulfonic Acid Lakes



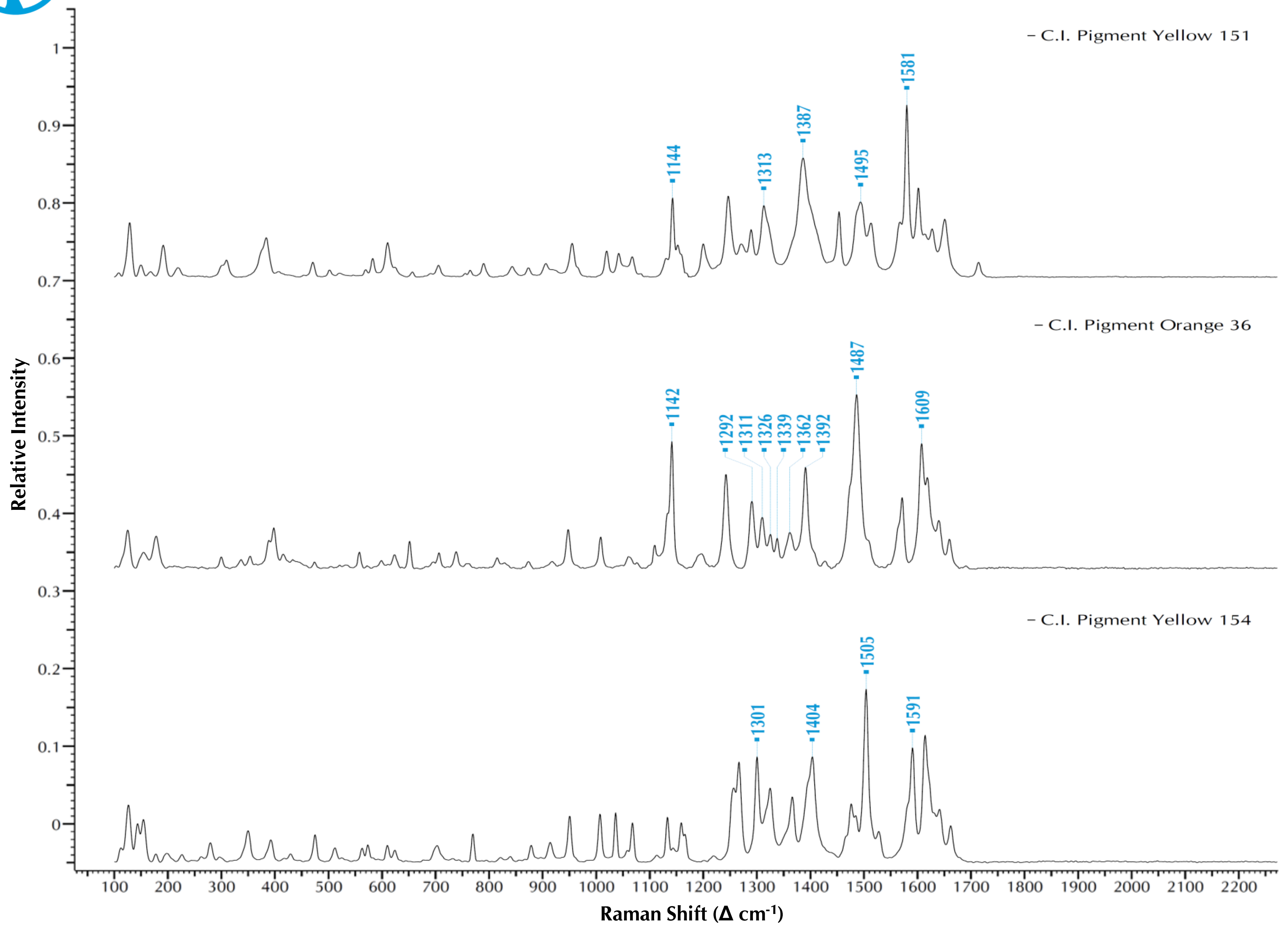
Benzimidazolone – Group 1



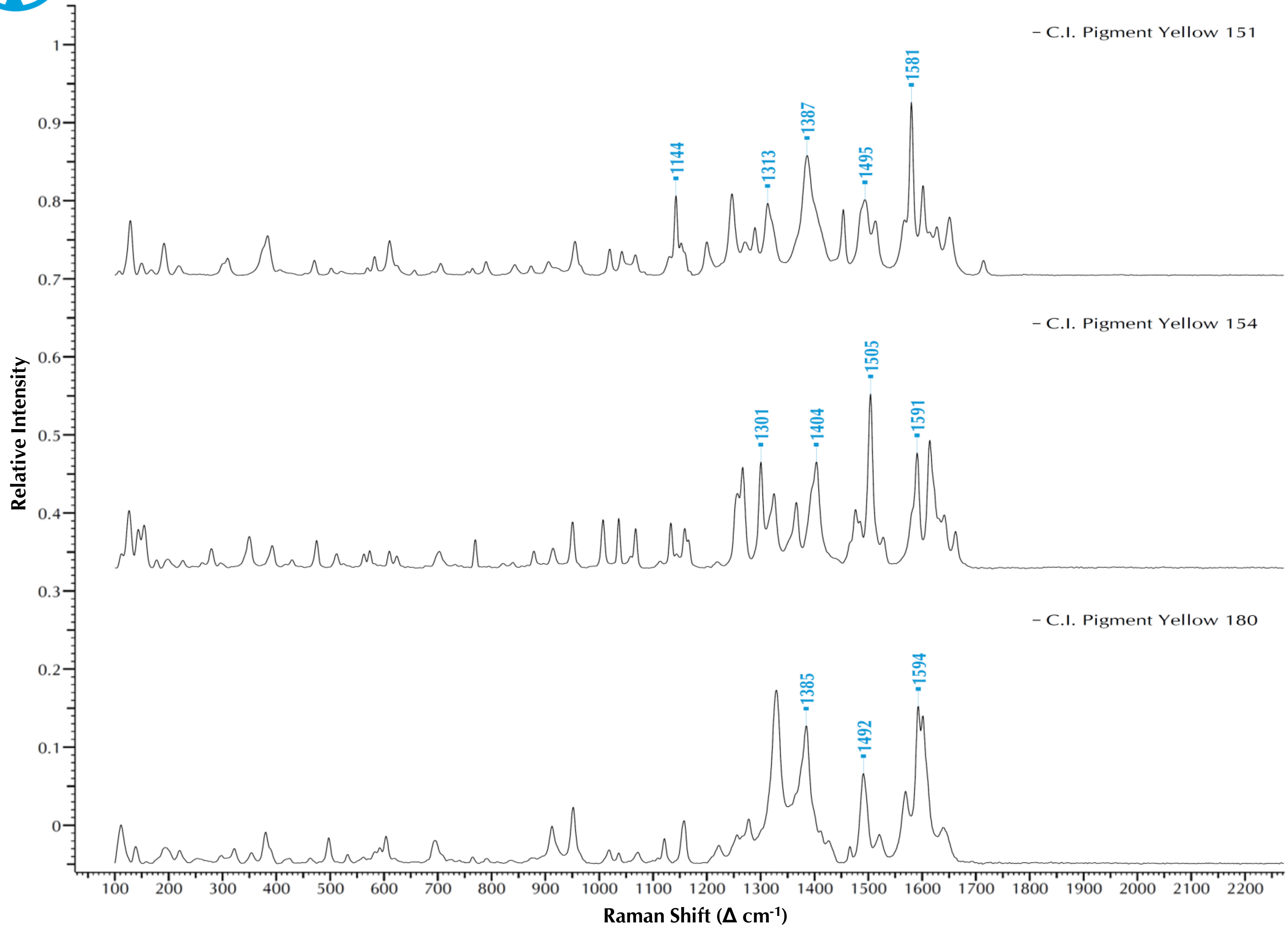
Benzimidazolone – Group 1



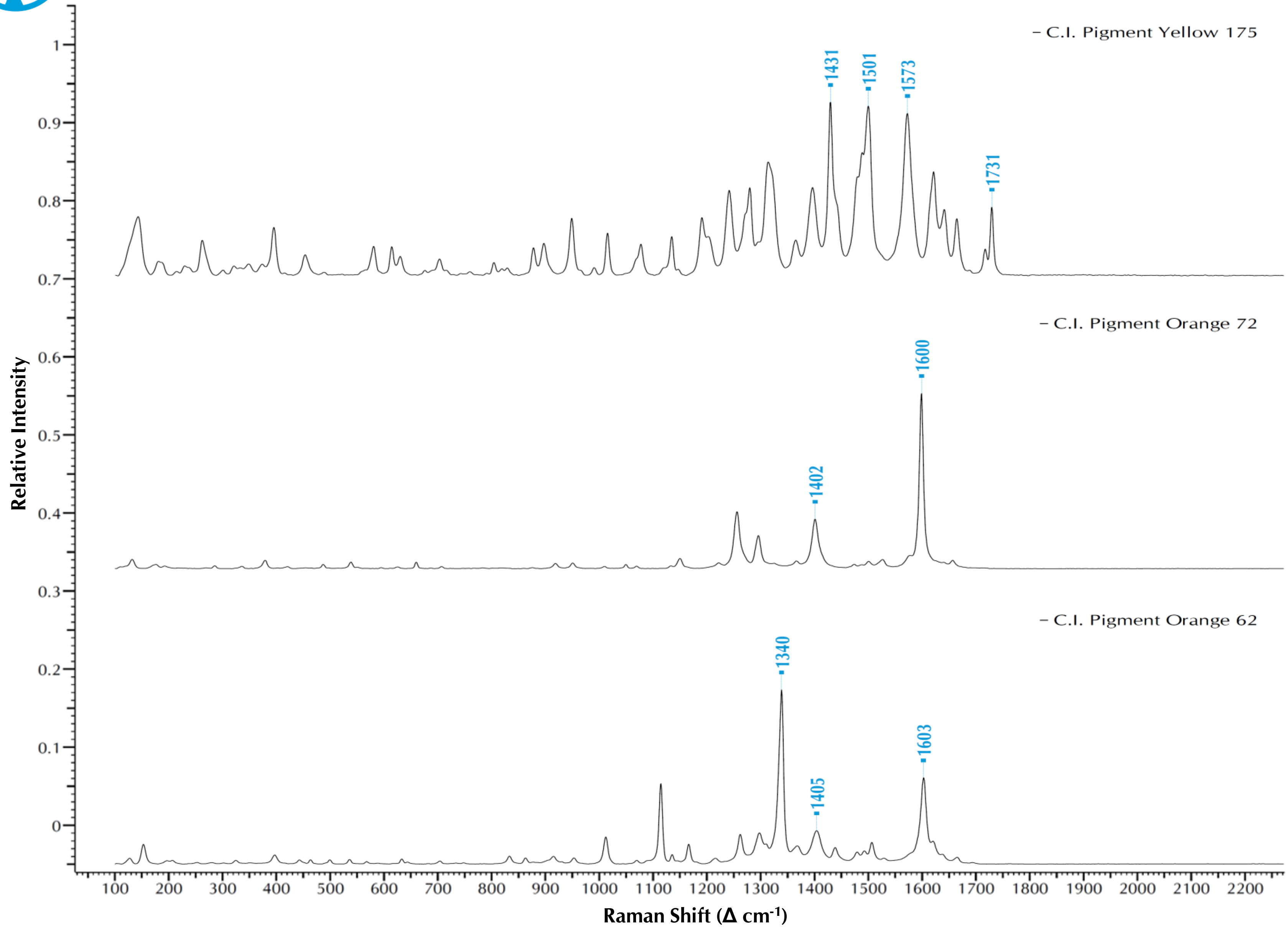
Benzimidazolone – Group 1



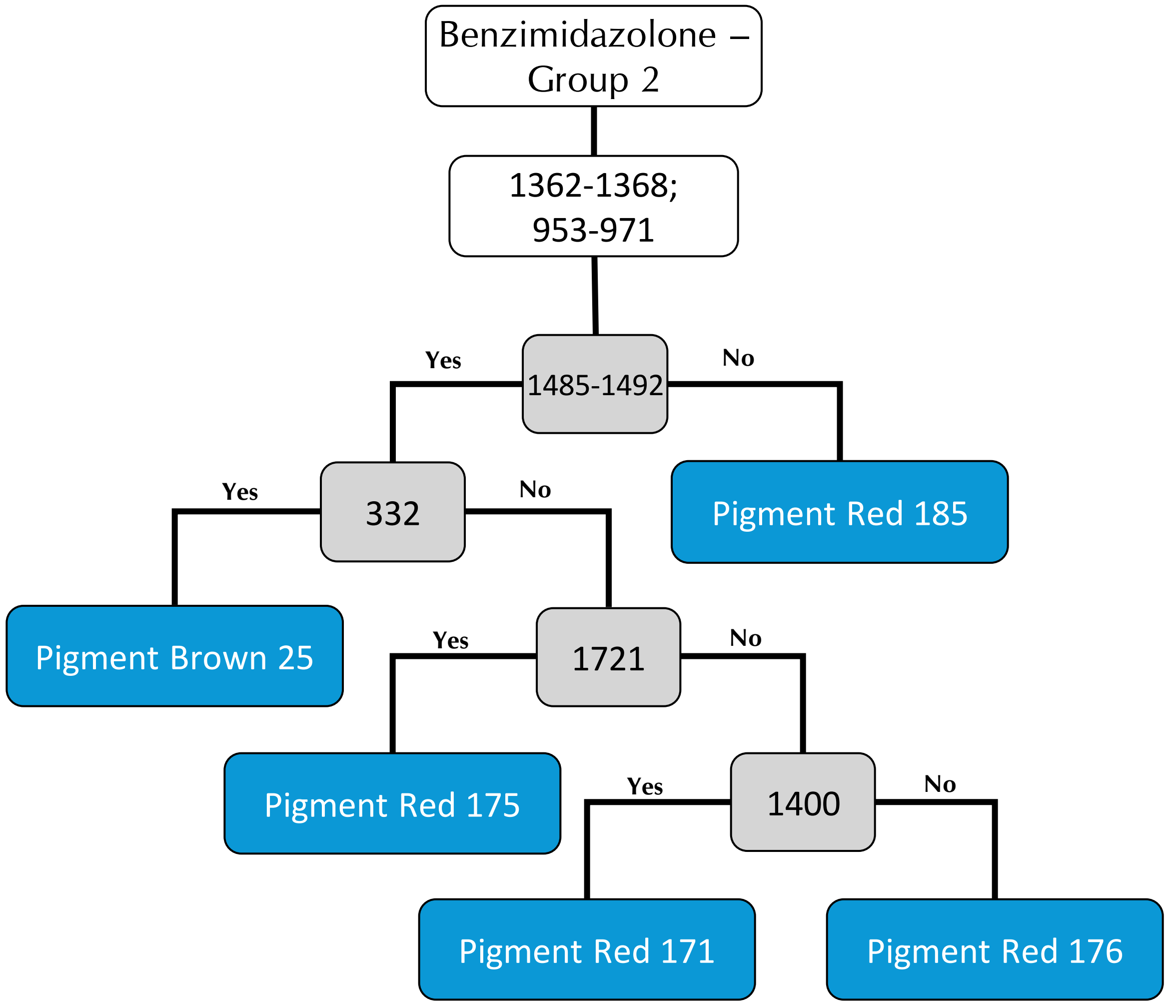
Benzimidazolone – Group 1



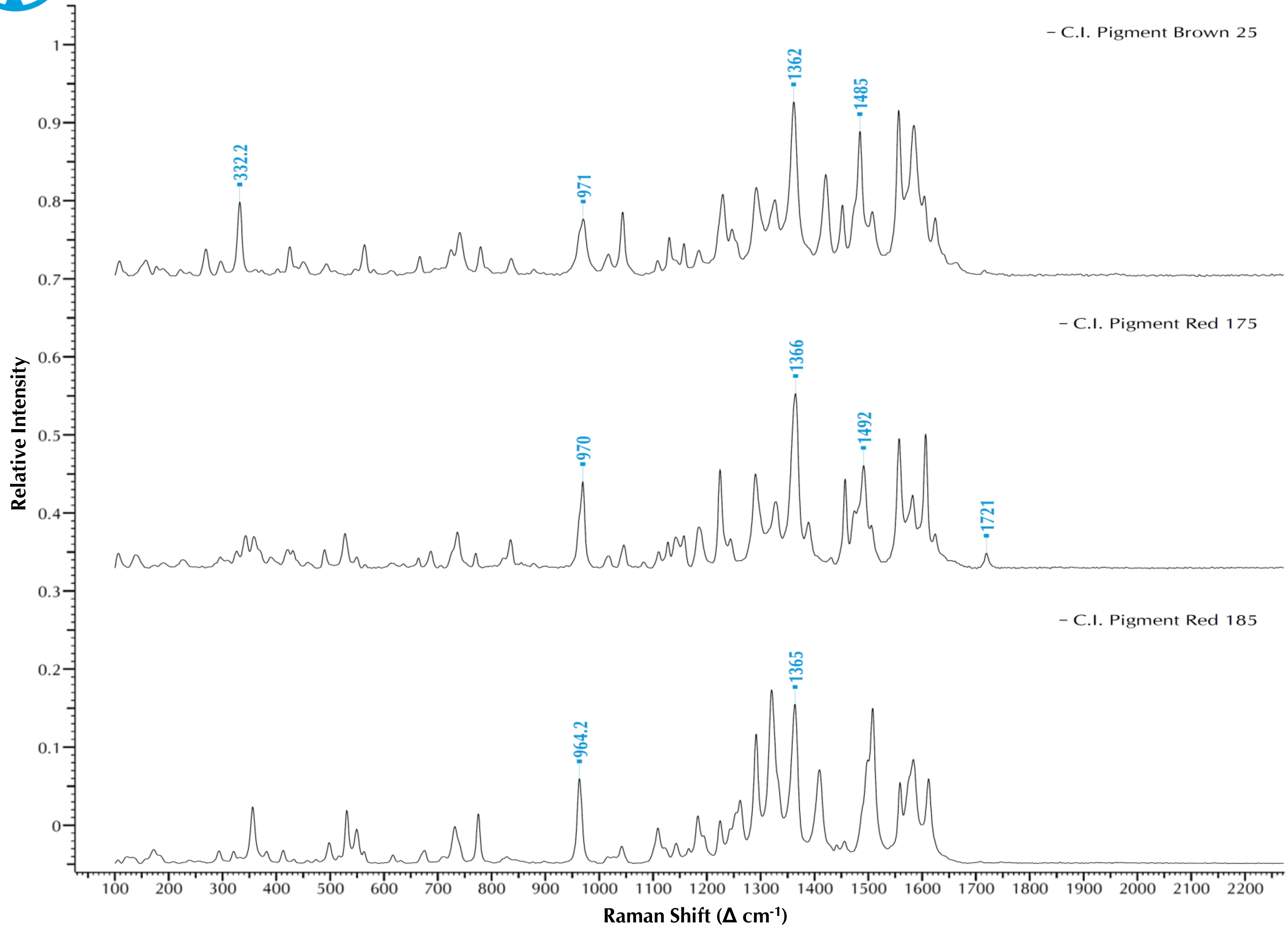
Benzimidazolone – Group 1



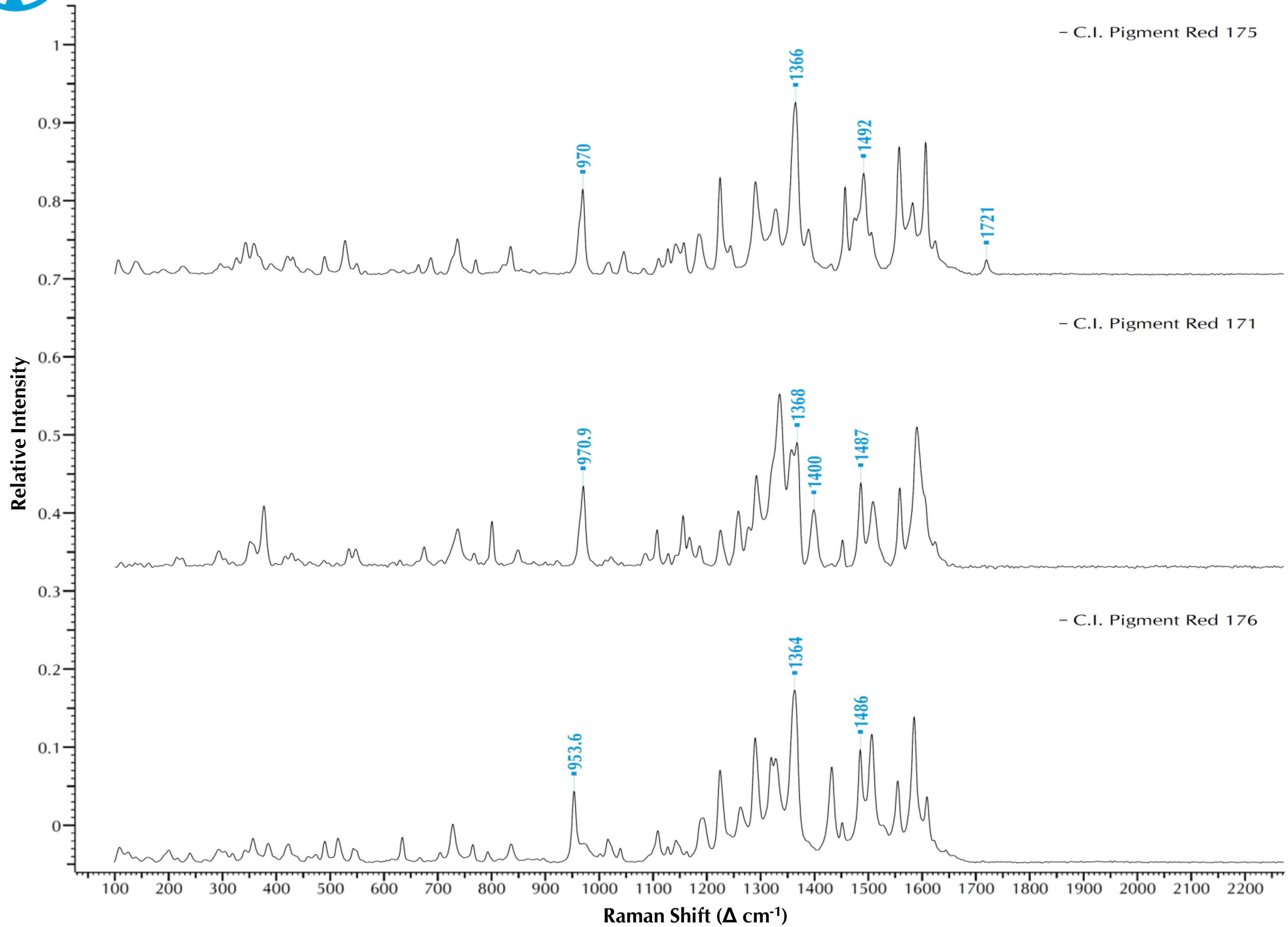
Benzimidazolone – Group 2



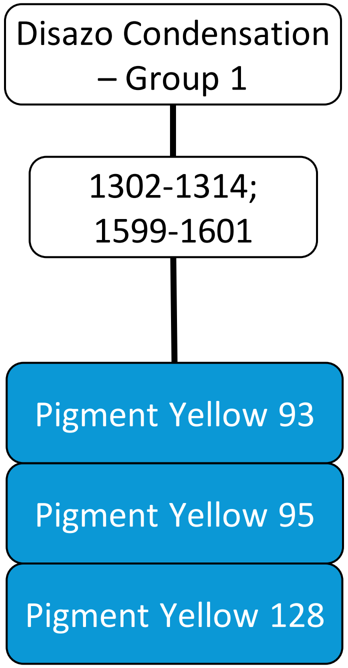
Benzimidazolone – Group 2



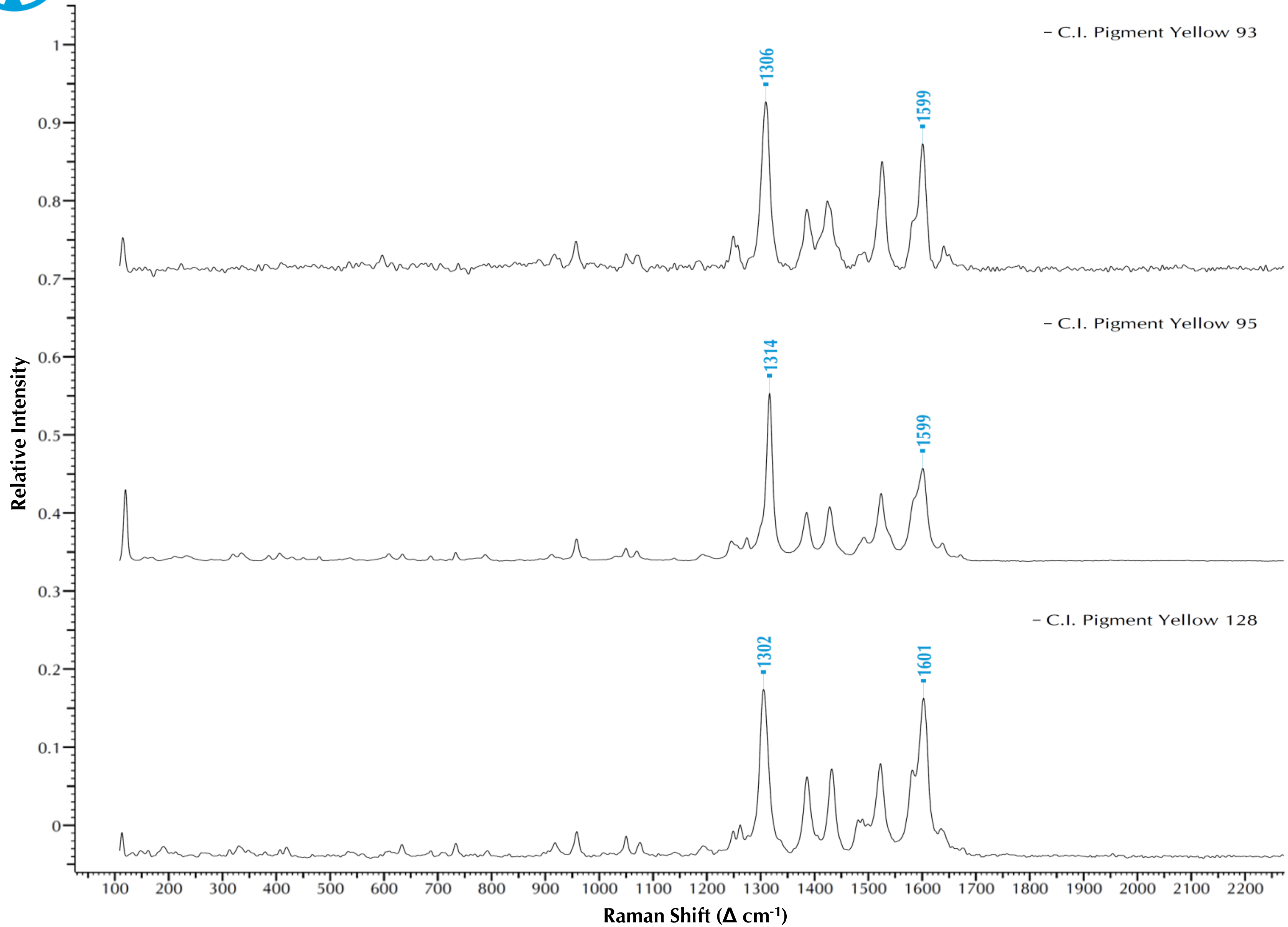
Benzimidazolone – Group 2



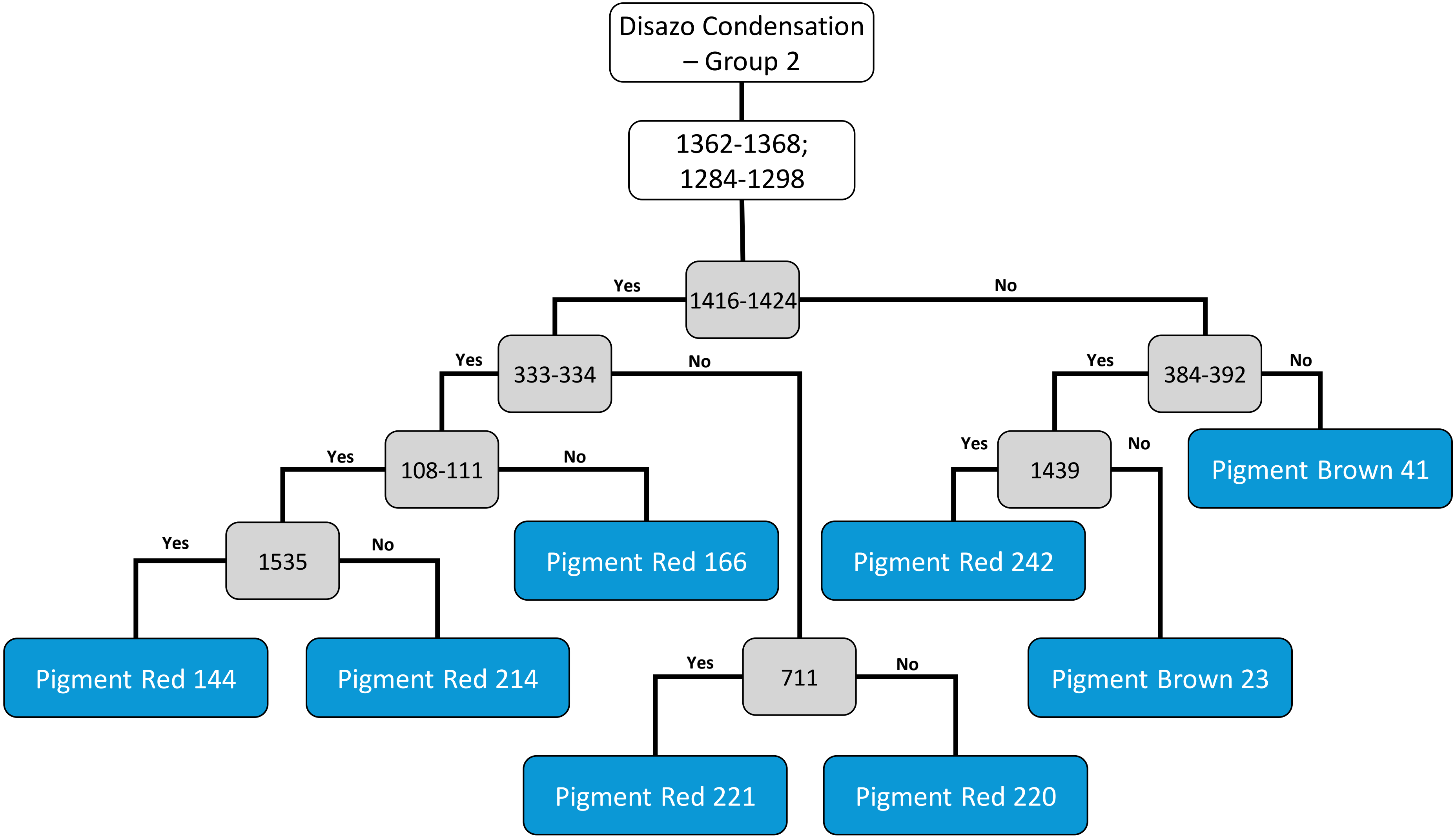
Disazo Condensation – Group 1



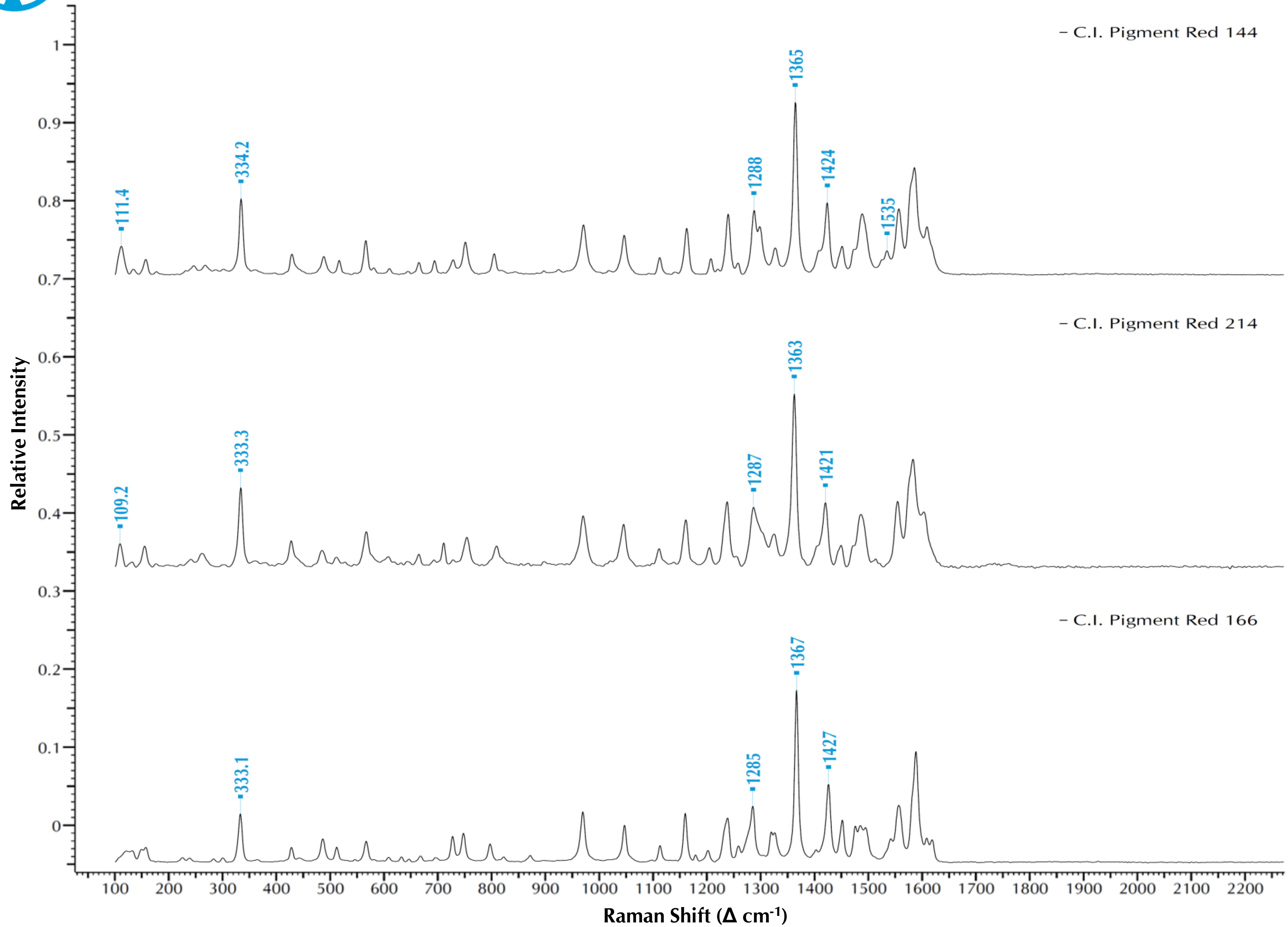
Disazo Condensation – Group 1



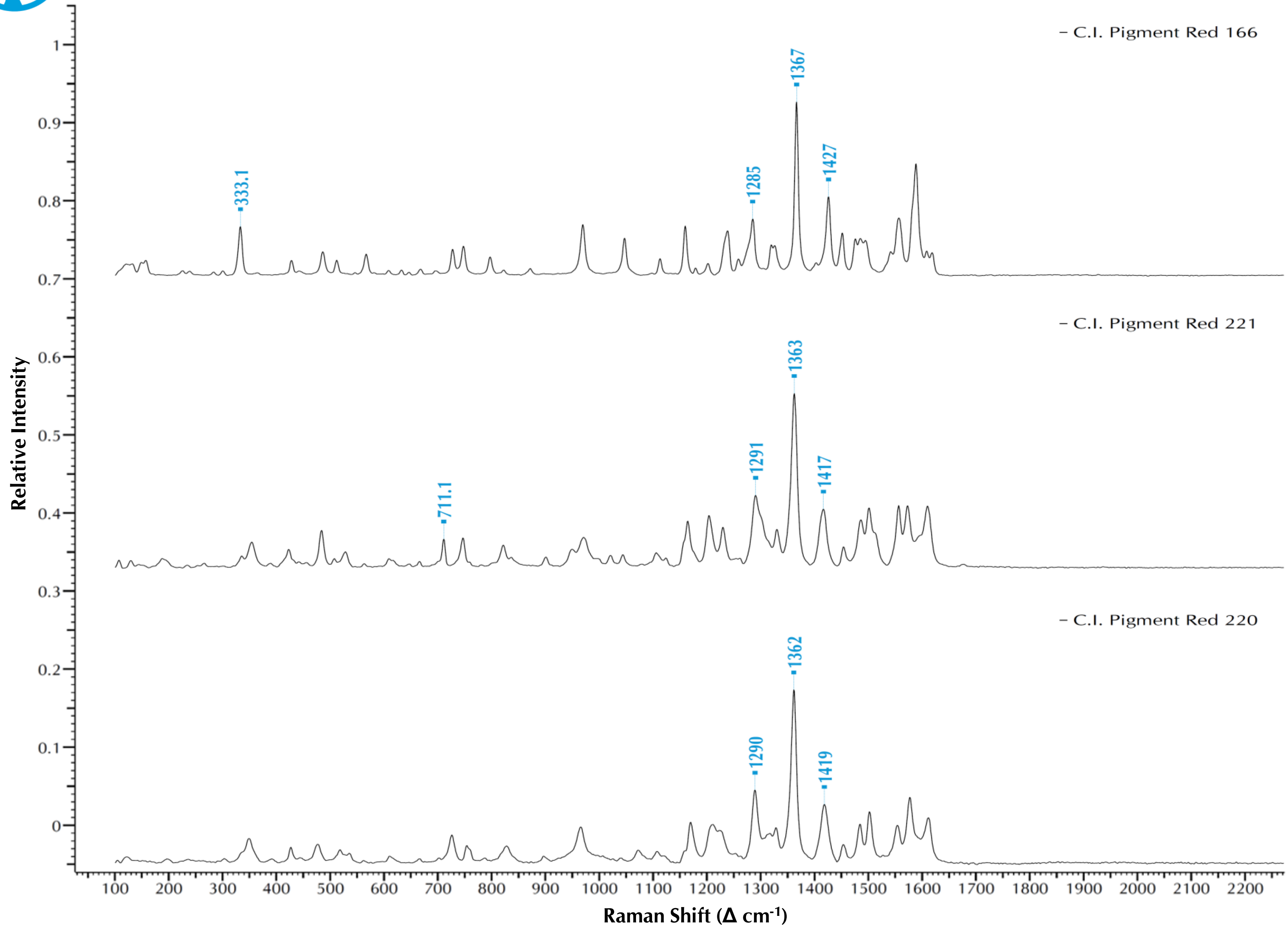
Disazo Condensation – Group 2



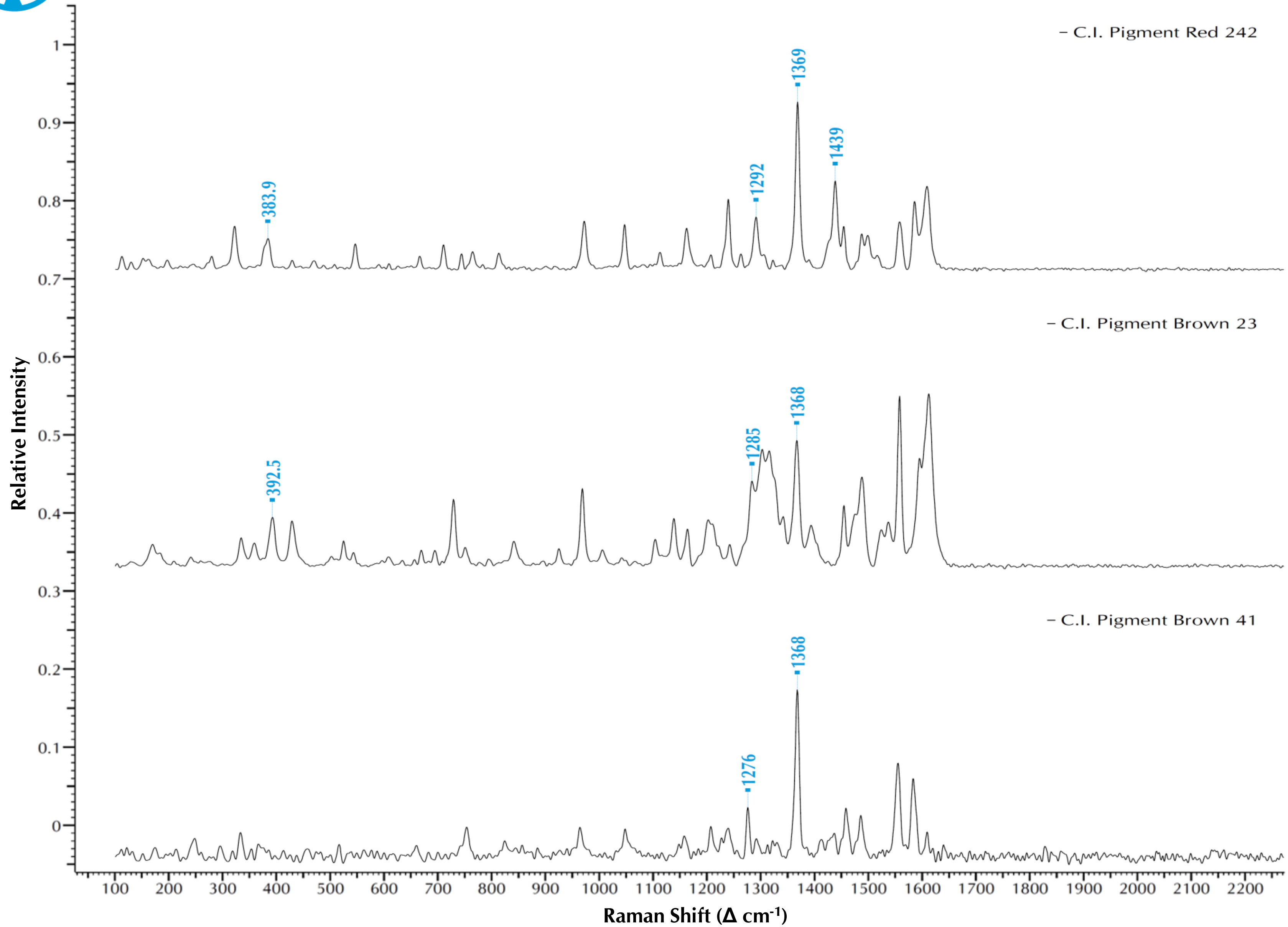
Disazo Condensation – Group 2



Disazo Condensation – Group 2



Disazo Condensation – Group 2



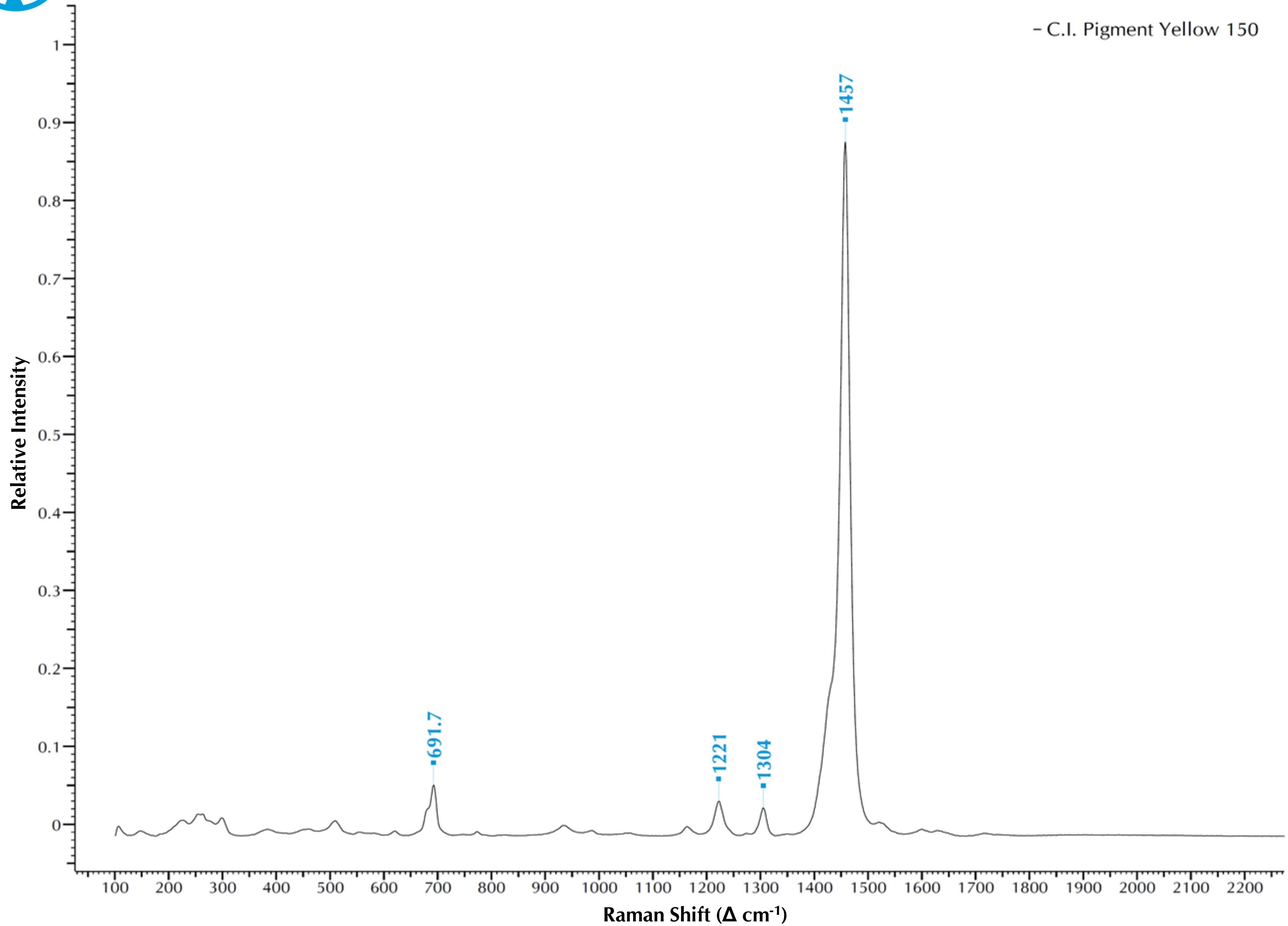
Metal Complex – Azo - Ni

Metal Complex – Azo - Ni

1457

Pigment Yellow 150

Metal Complex – Azo - Ni



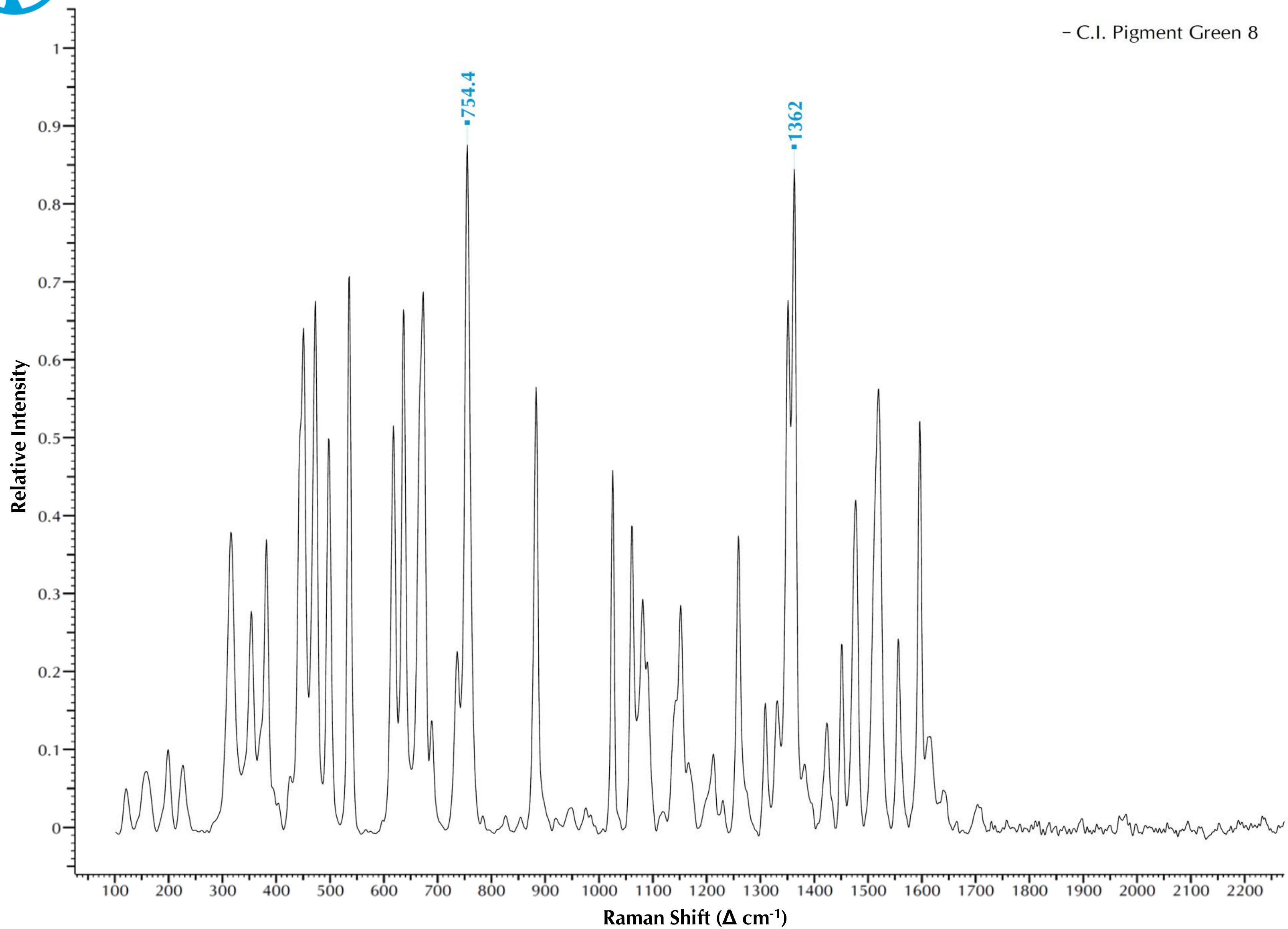
Metal Complex – Azo – Fe/Na

Metal Complex – Azo – Fe/Na

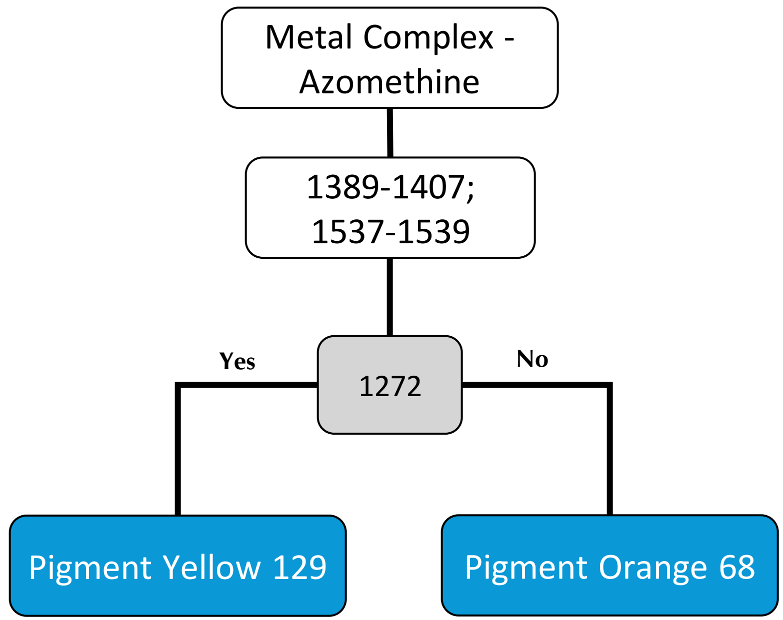
1362;
754

Pigment Green 8

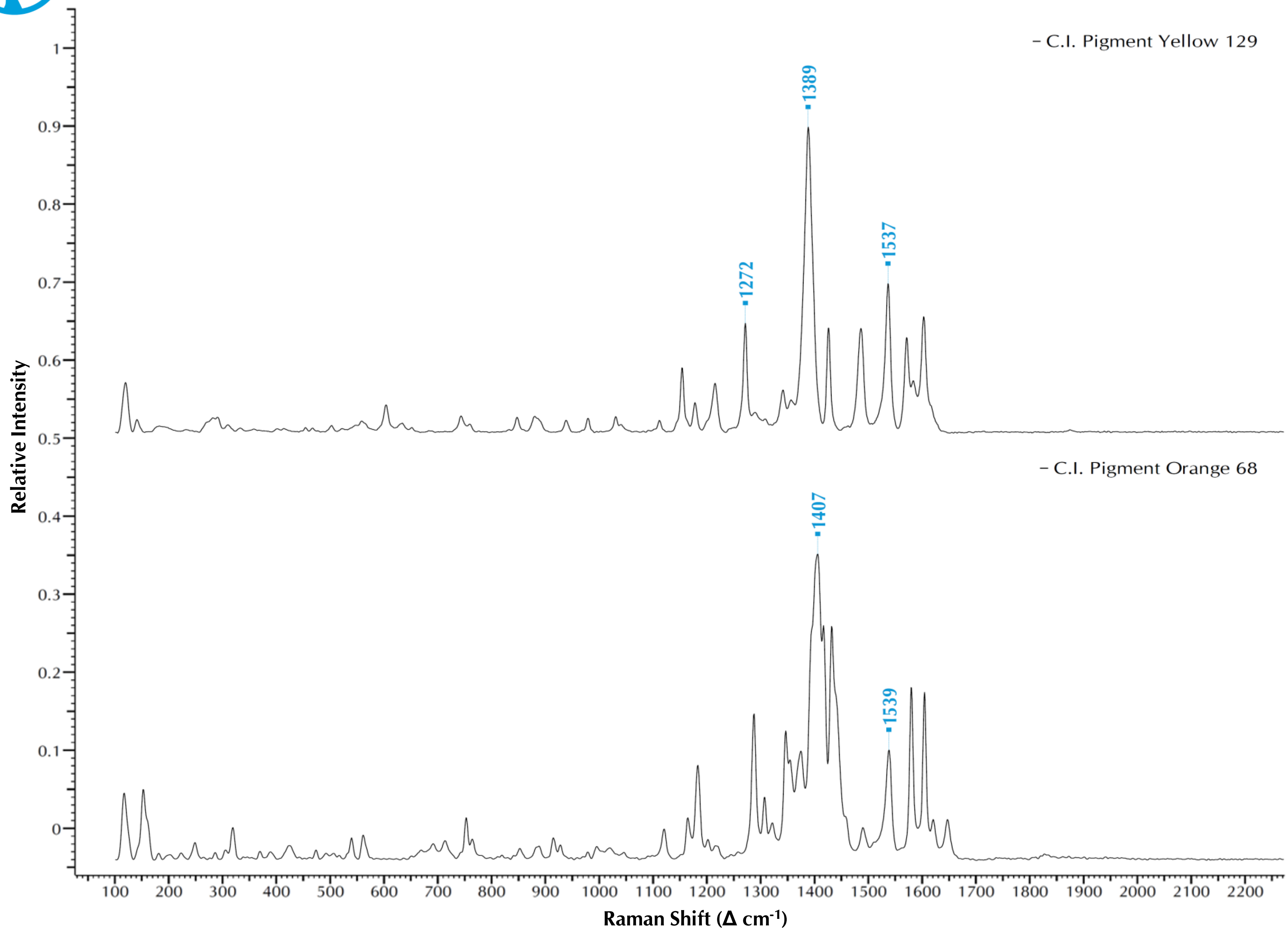
Metal Complex – Azo – Fe/Na



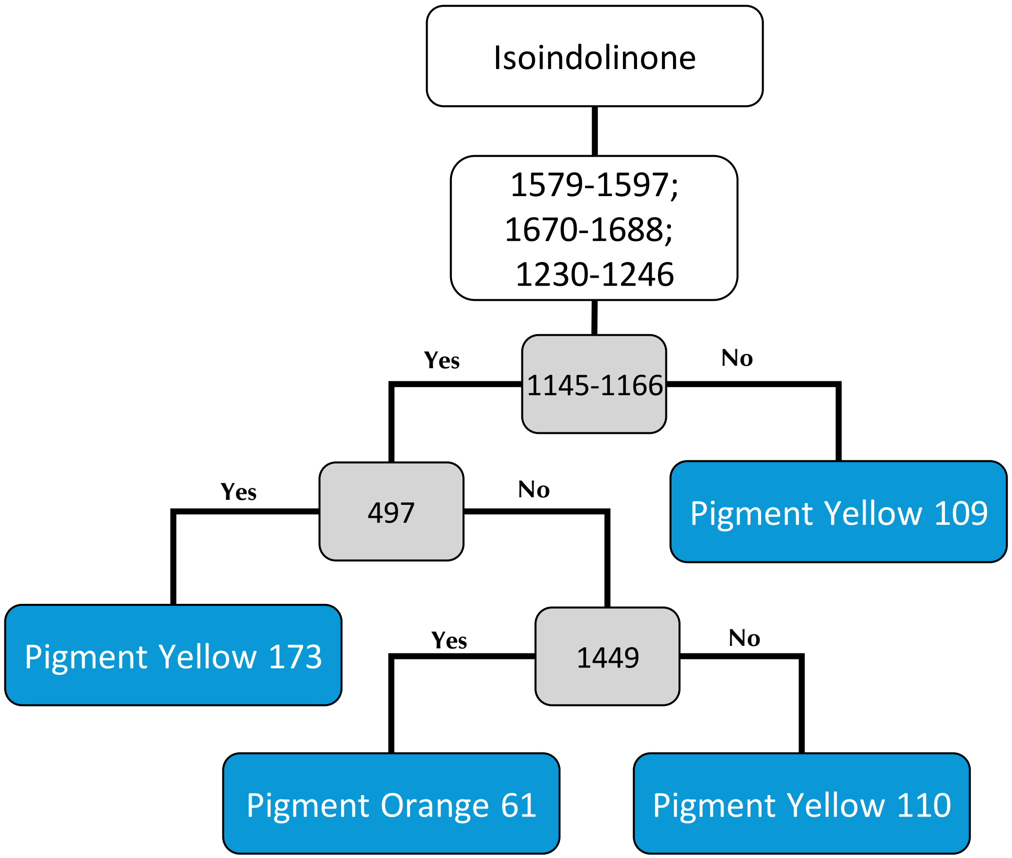
Metal Complex – Azomethine



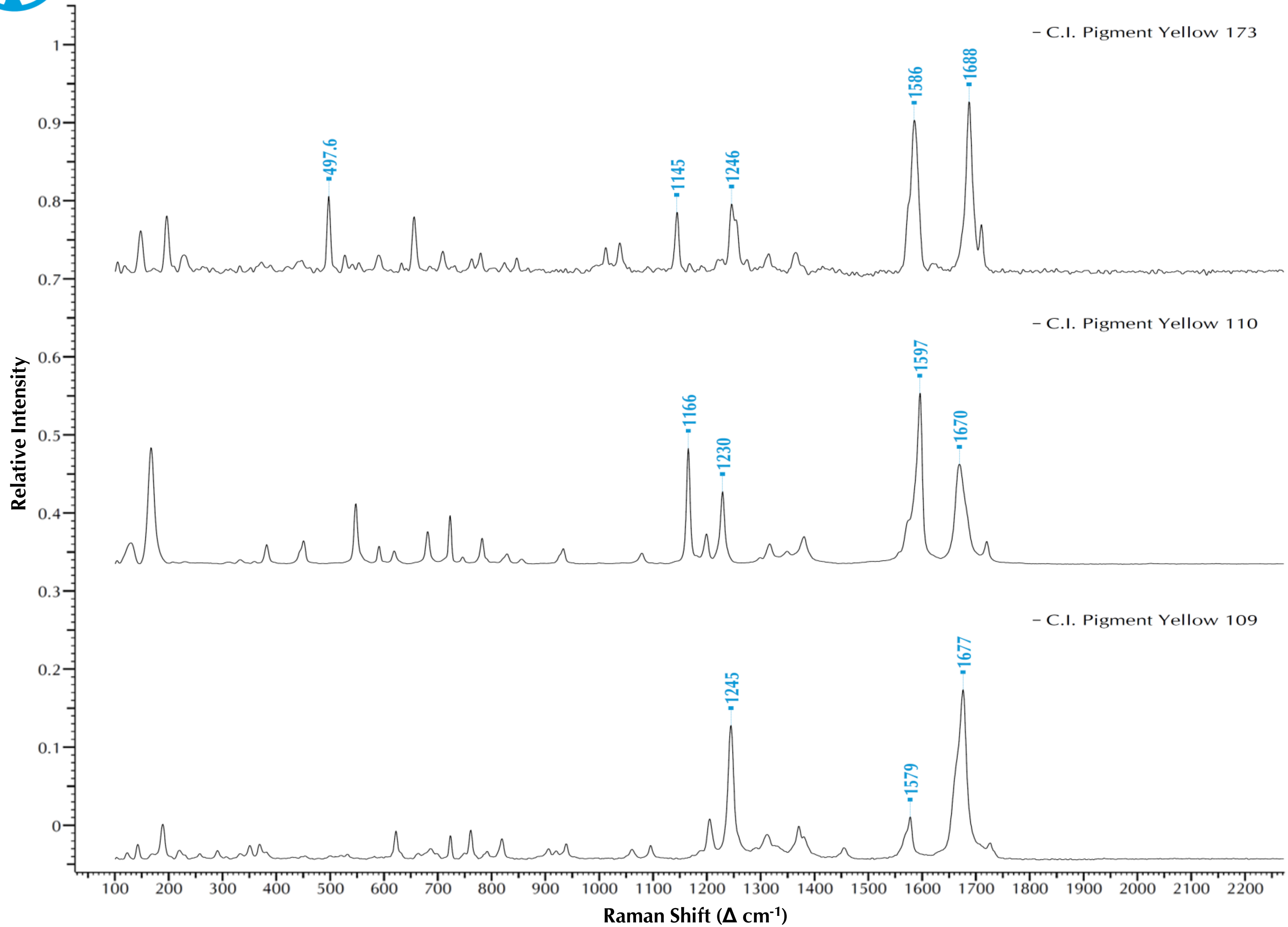
Metal Complex - Azomethine



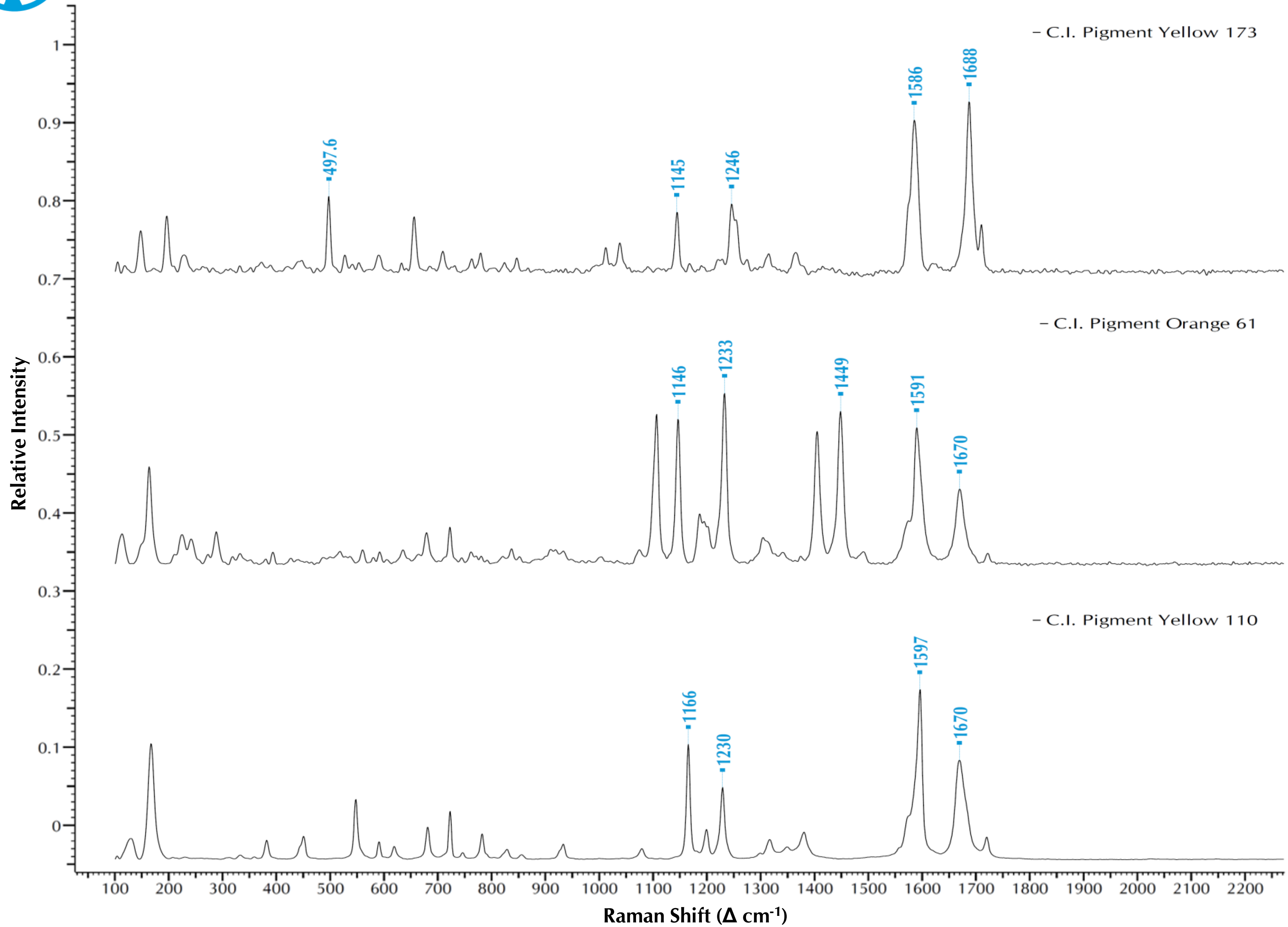
Isoindolinone



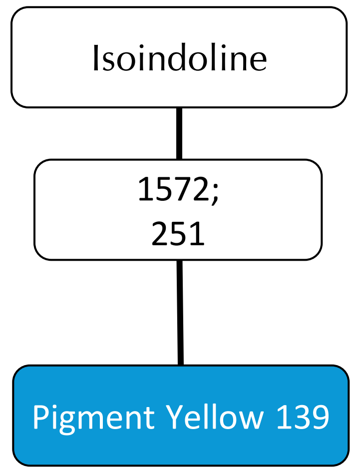
Isoindolinone



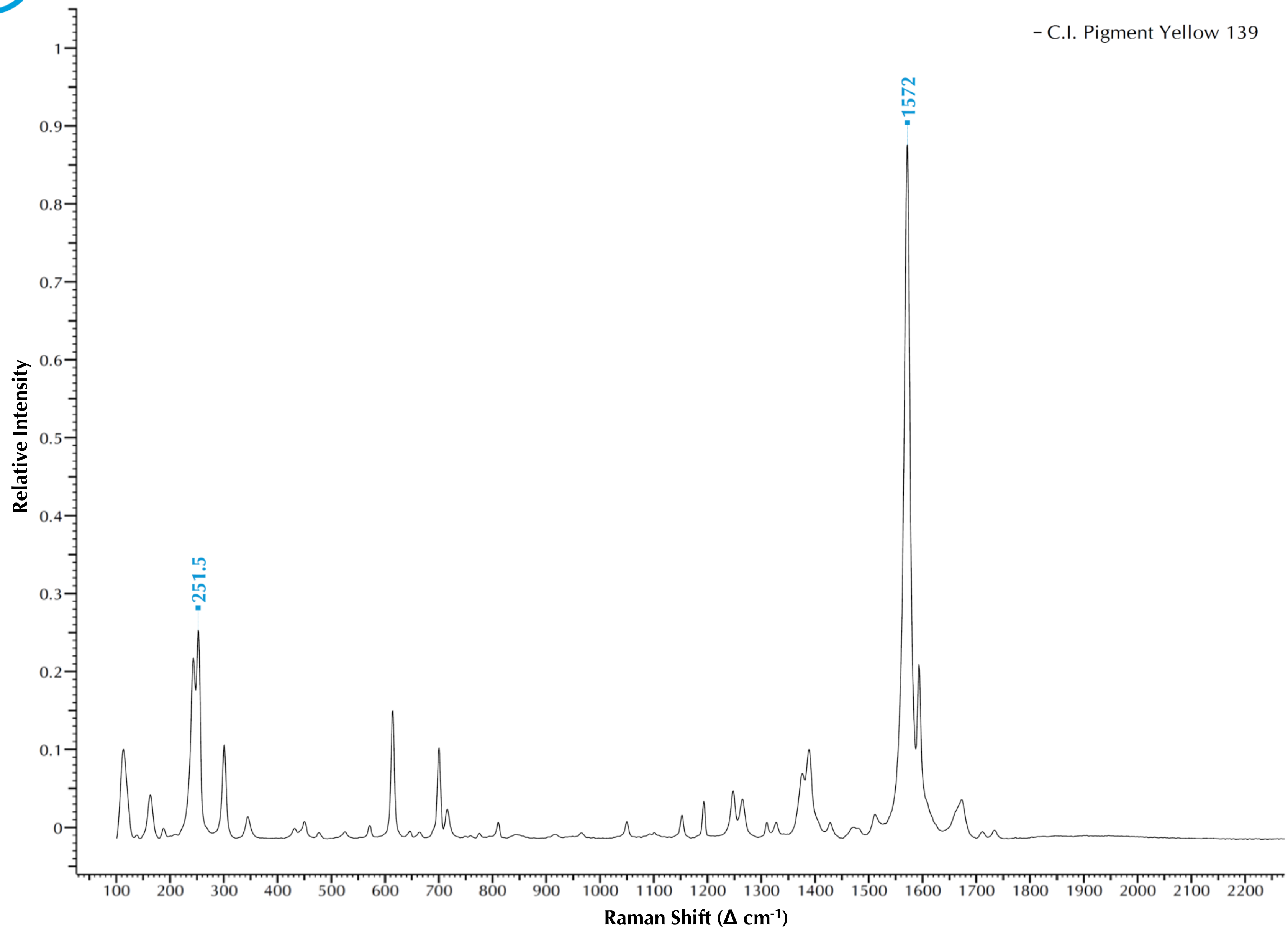
Isoindolinone



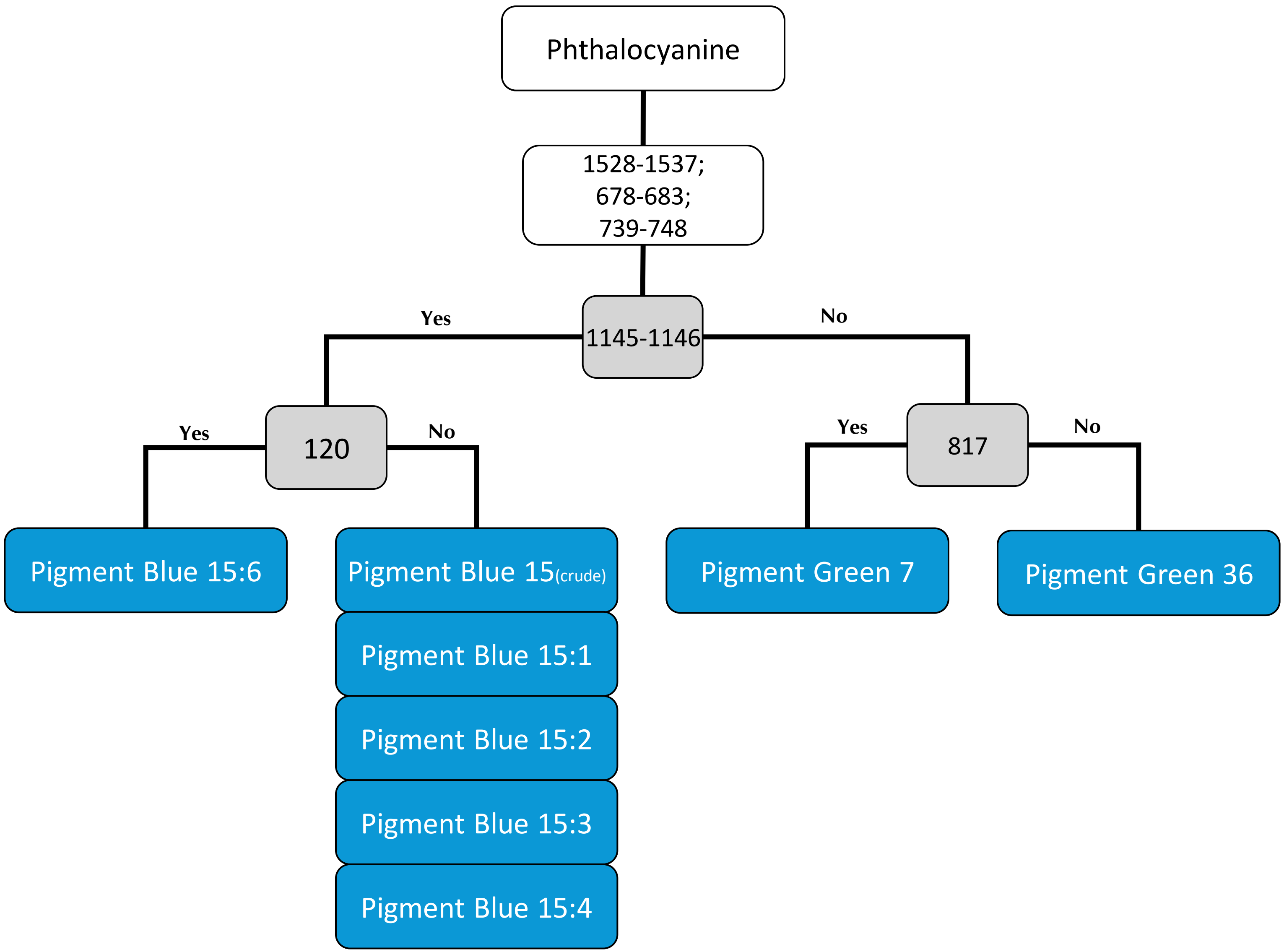
Isoindoline



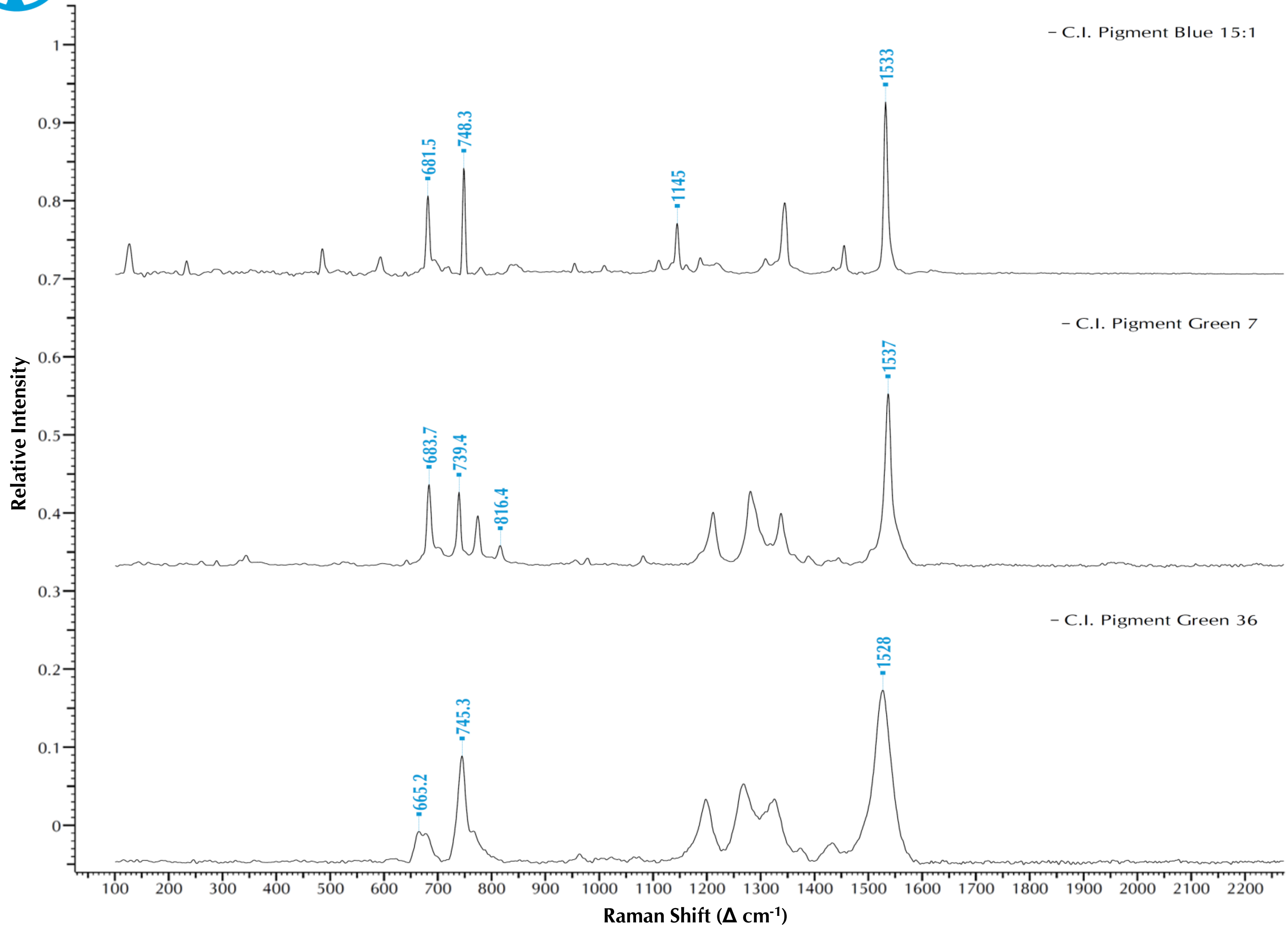
Isoindoline



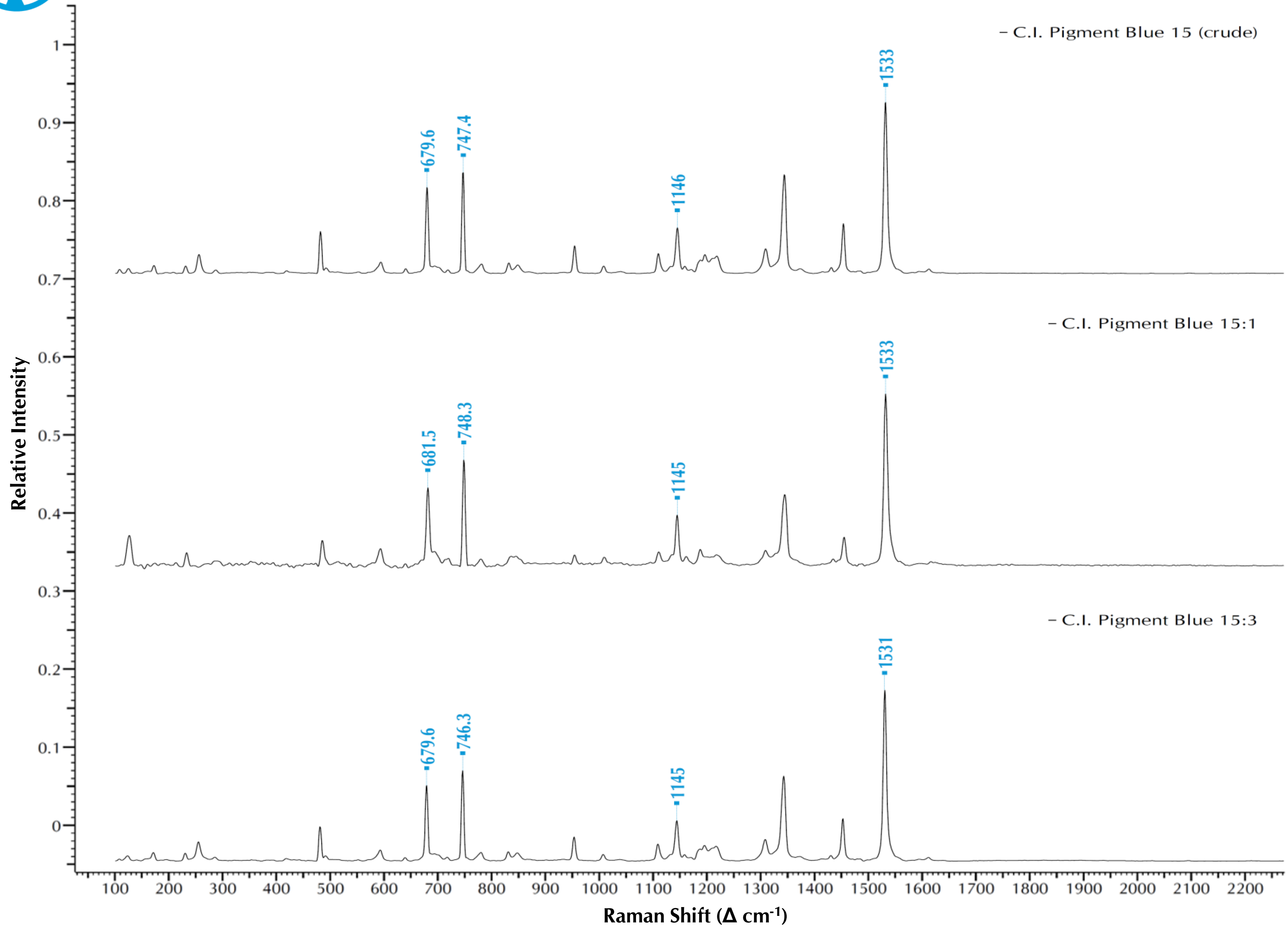
Phthalocyanine



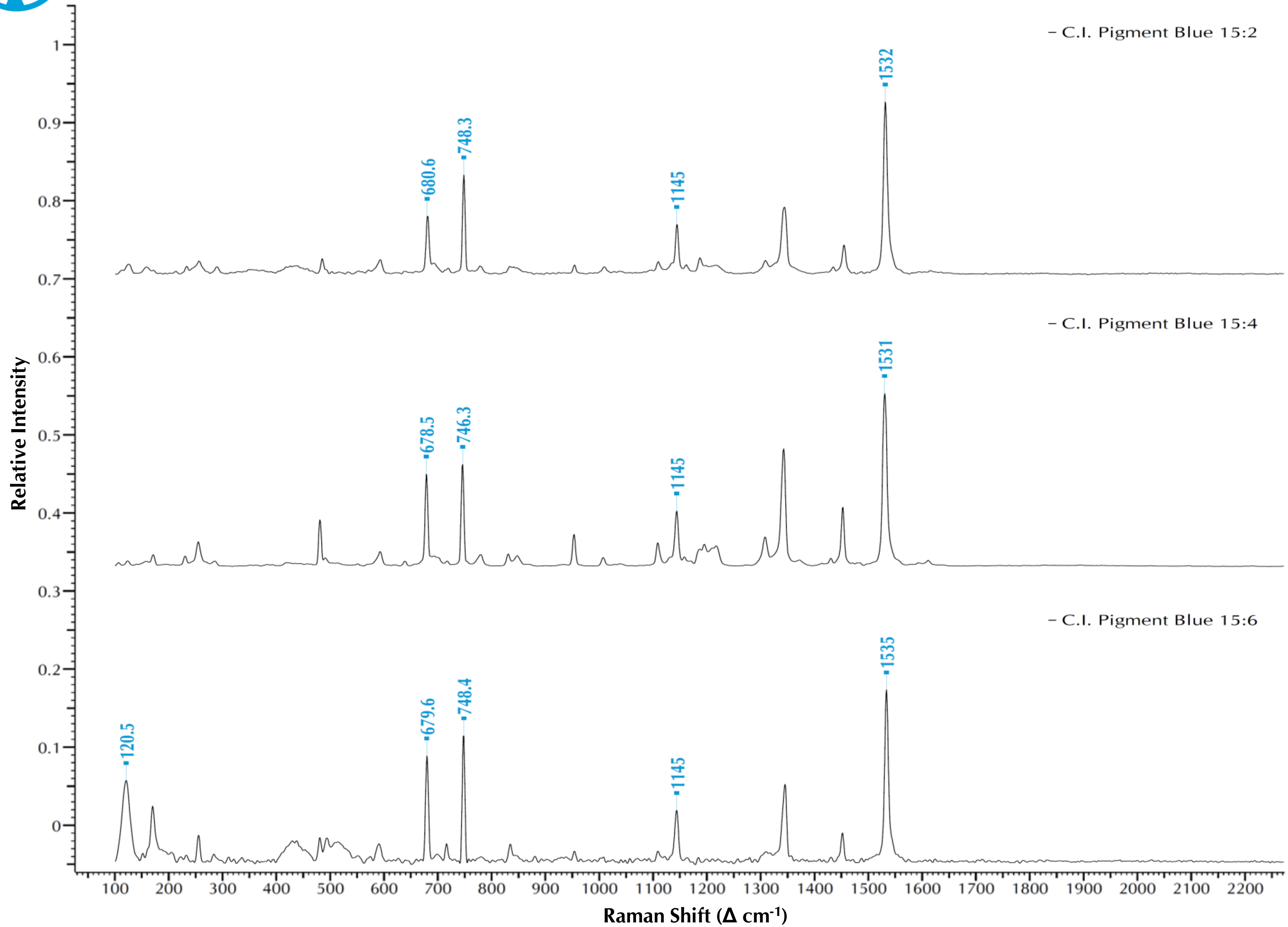
Phthalocyanine



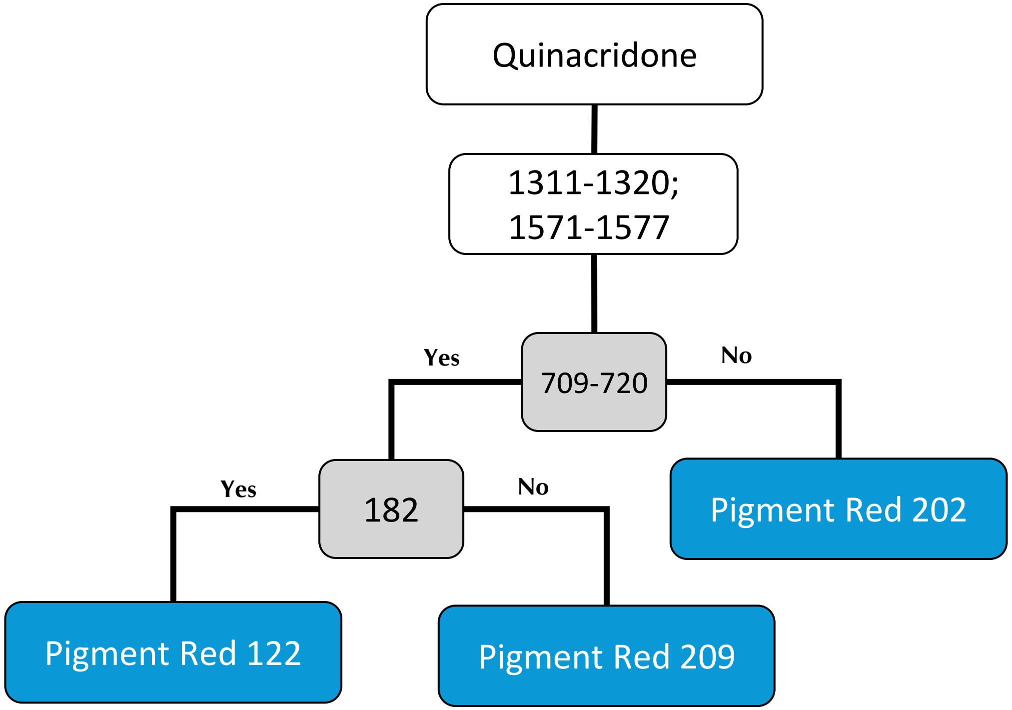
Phthalocyanine

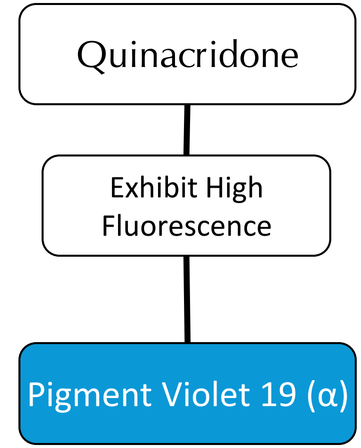


Phthalocyanine

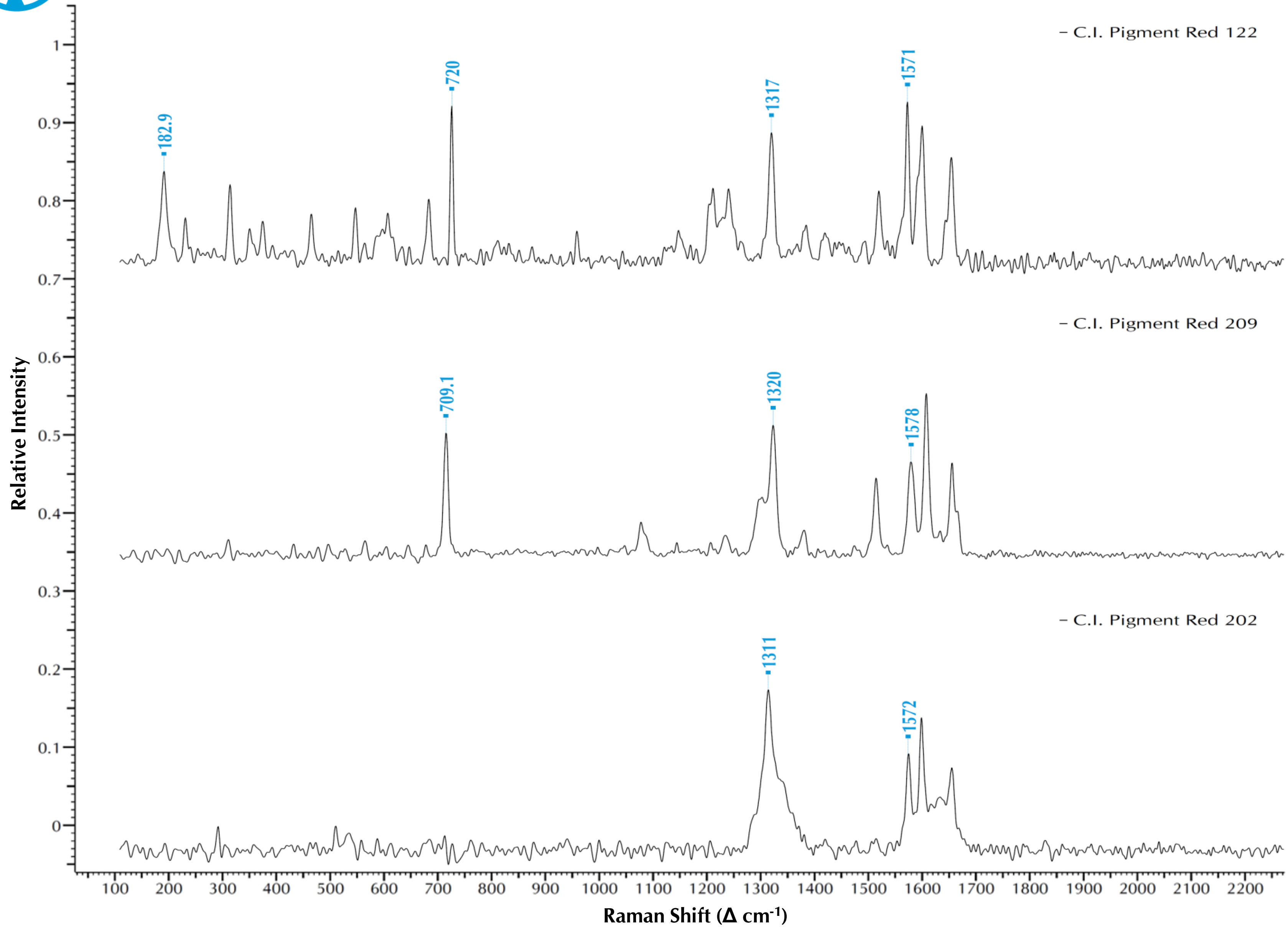


Quinacridone

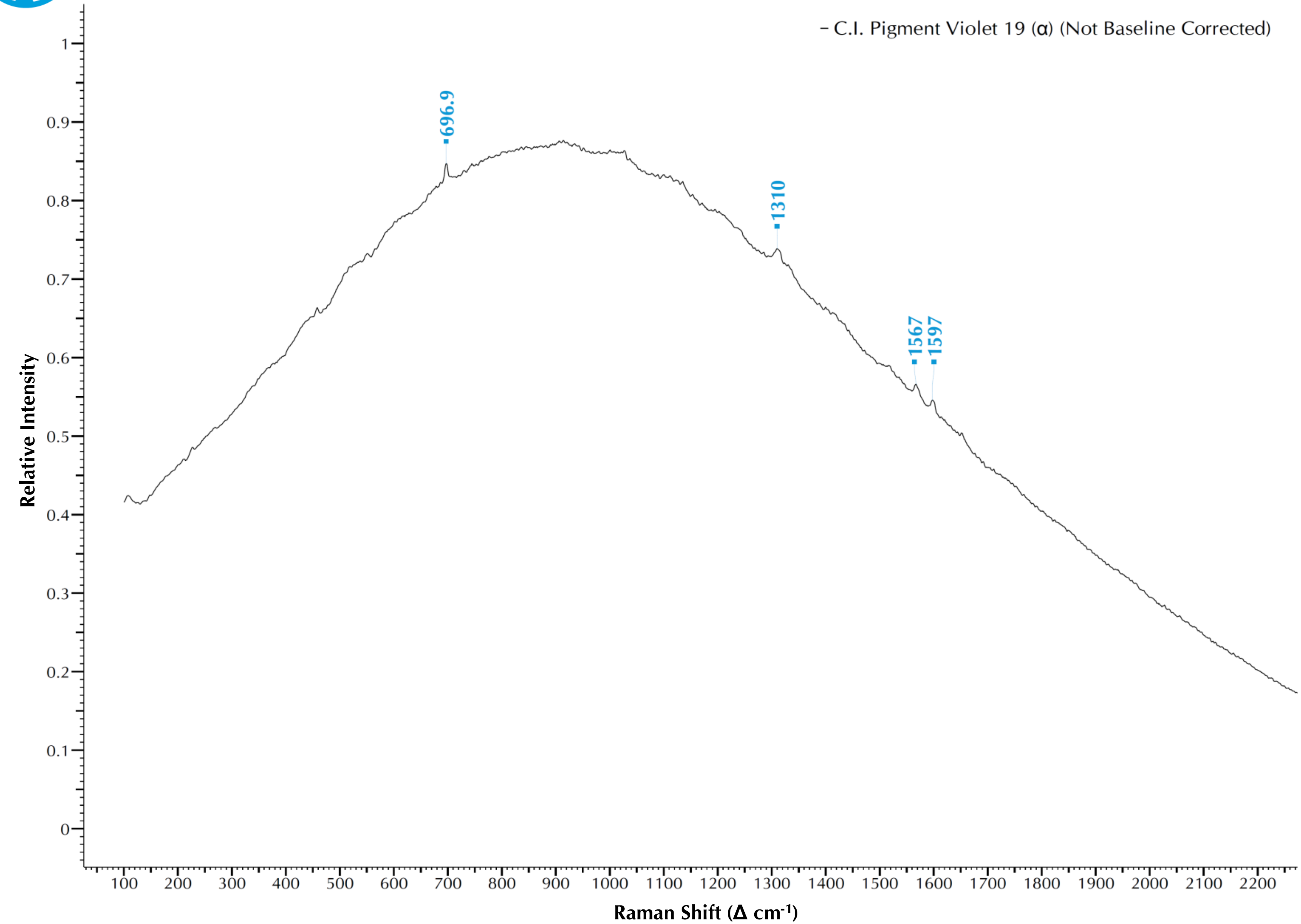




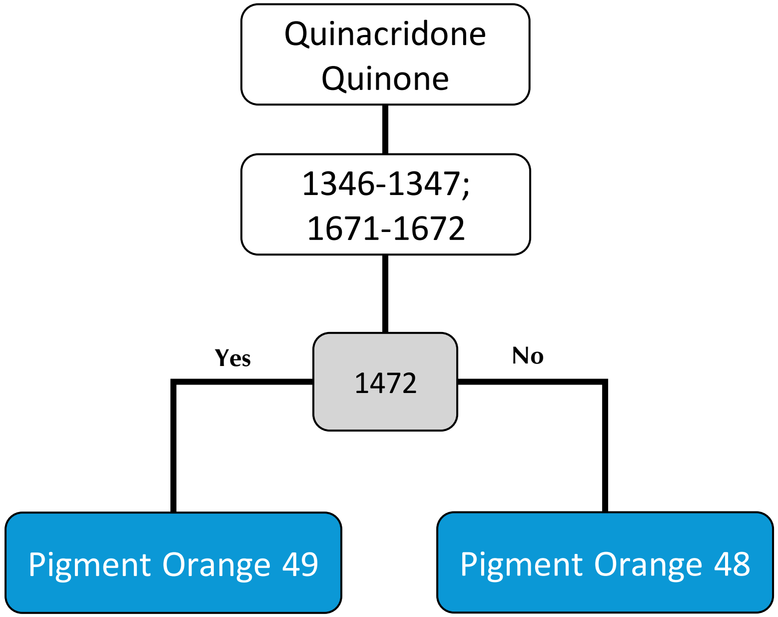
Quinacridone



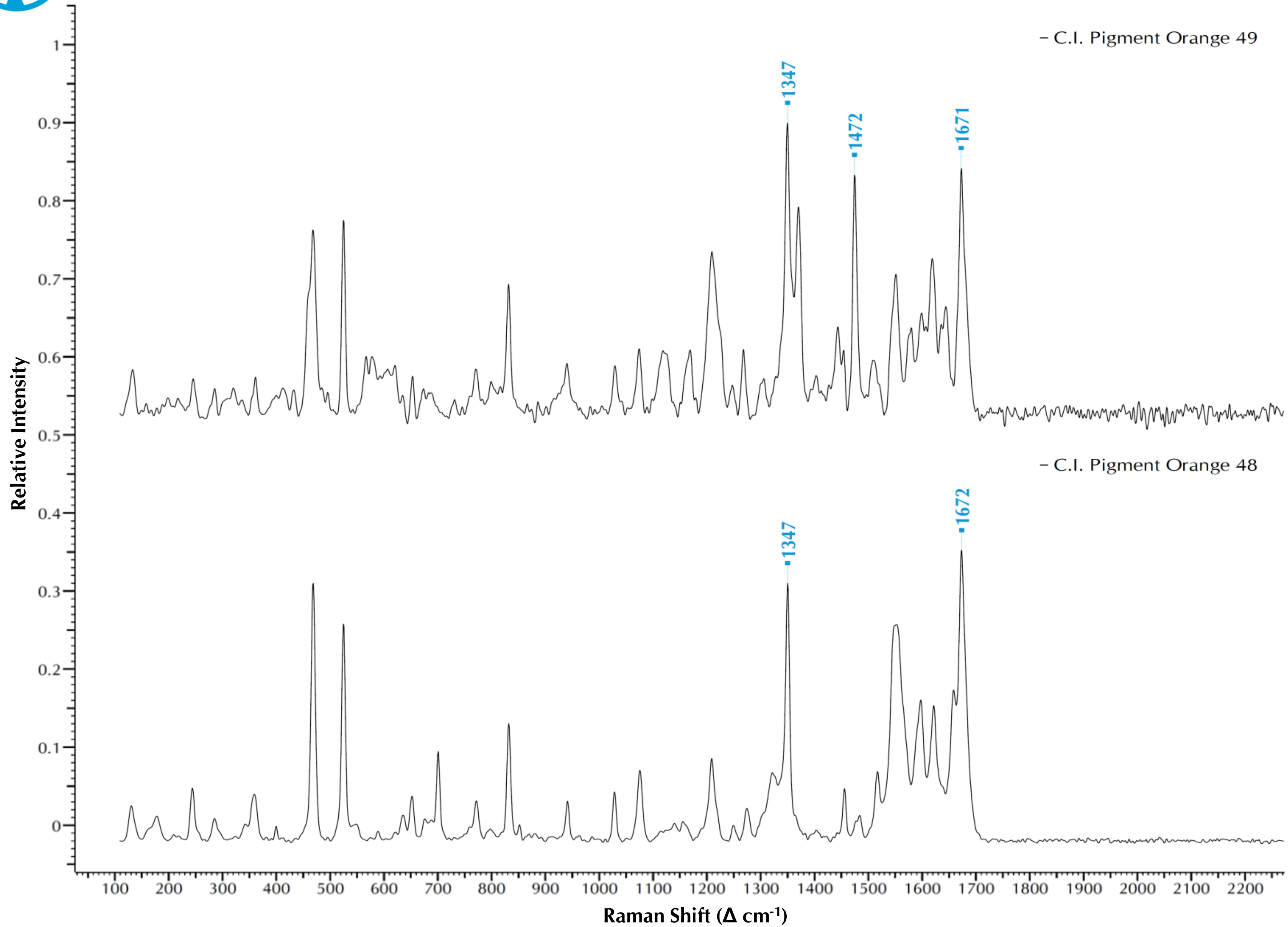
Quinacridone



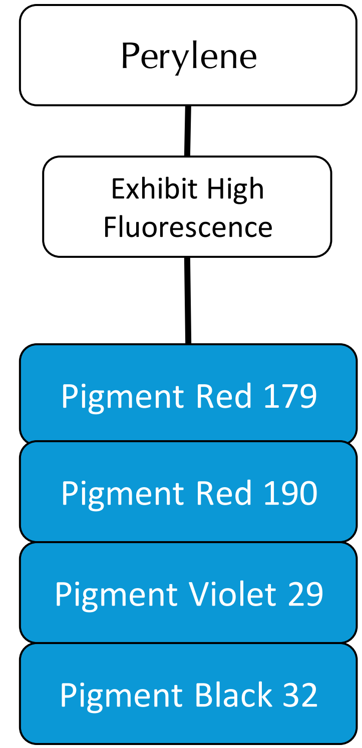
Quinacridone Quinone

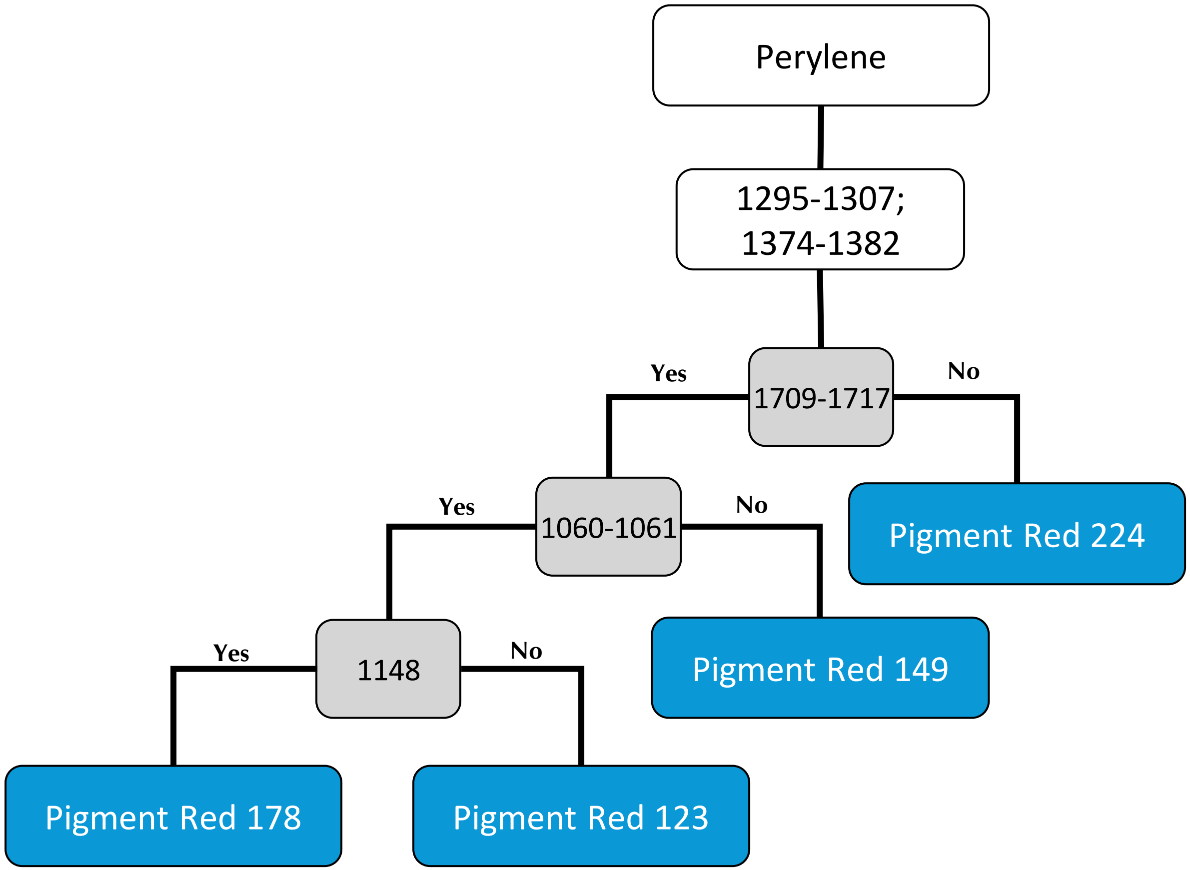


Quinacridone Quinone

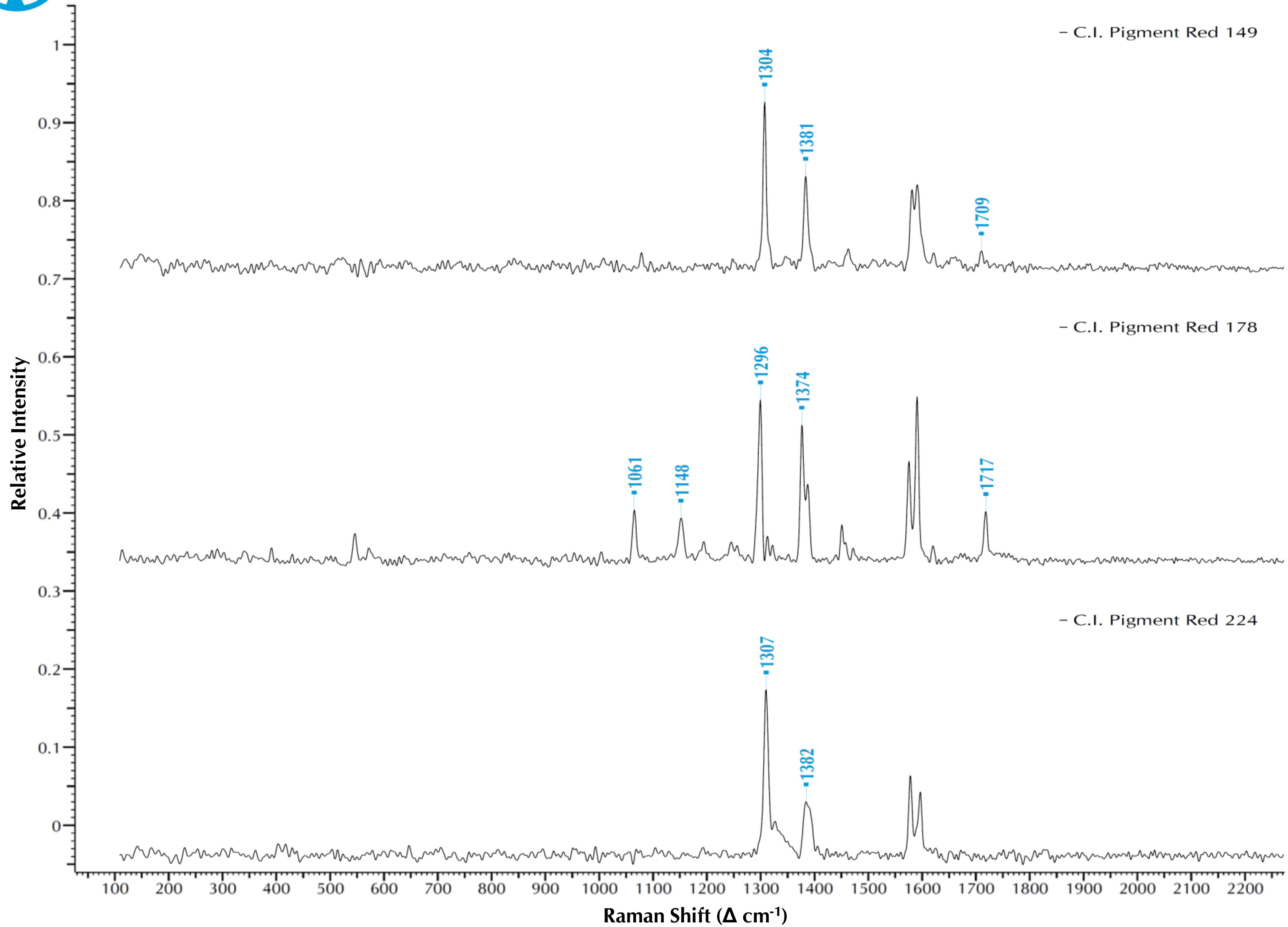


Perylene


Perylene
Exhibit High Fluorescence
Pigment Red 179
Pigment Red 190
Pigment Violet 29
Pigment Black 32

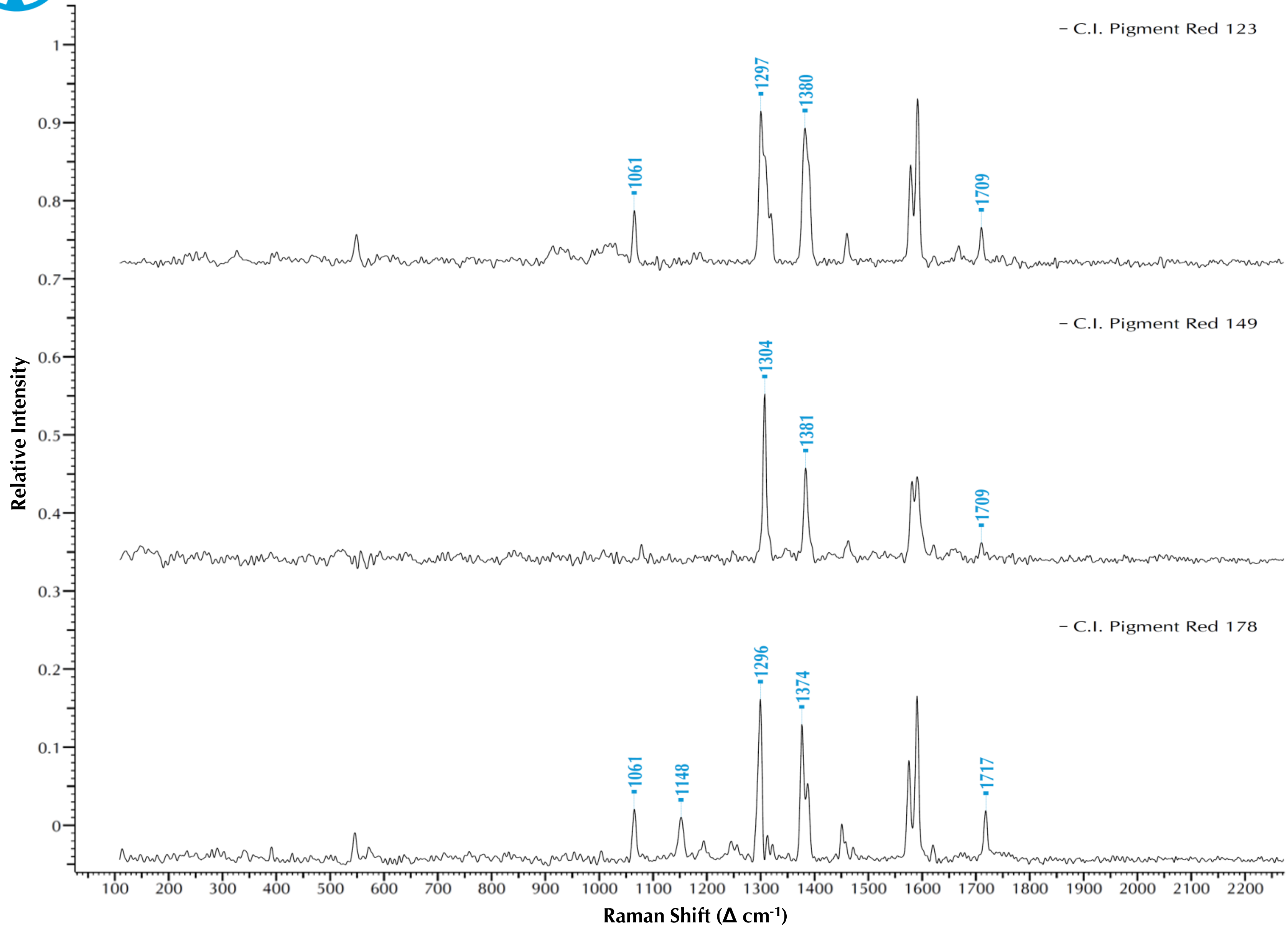

Perylene
1295-1307; 1374-1382
1709-1717
Yes
No
Pigment Red 224
1060-1061
Yes
No
Pigment Red 149
1148
Yes
No
Pigment Red 178
Pigment Red 123

Perylene



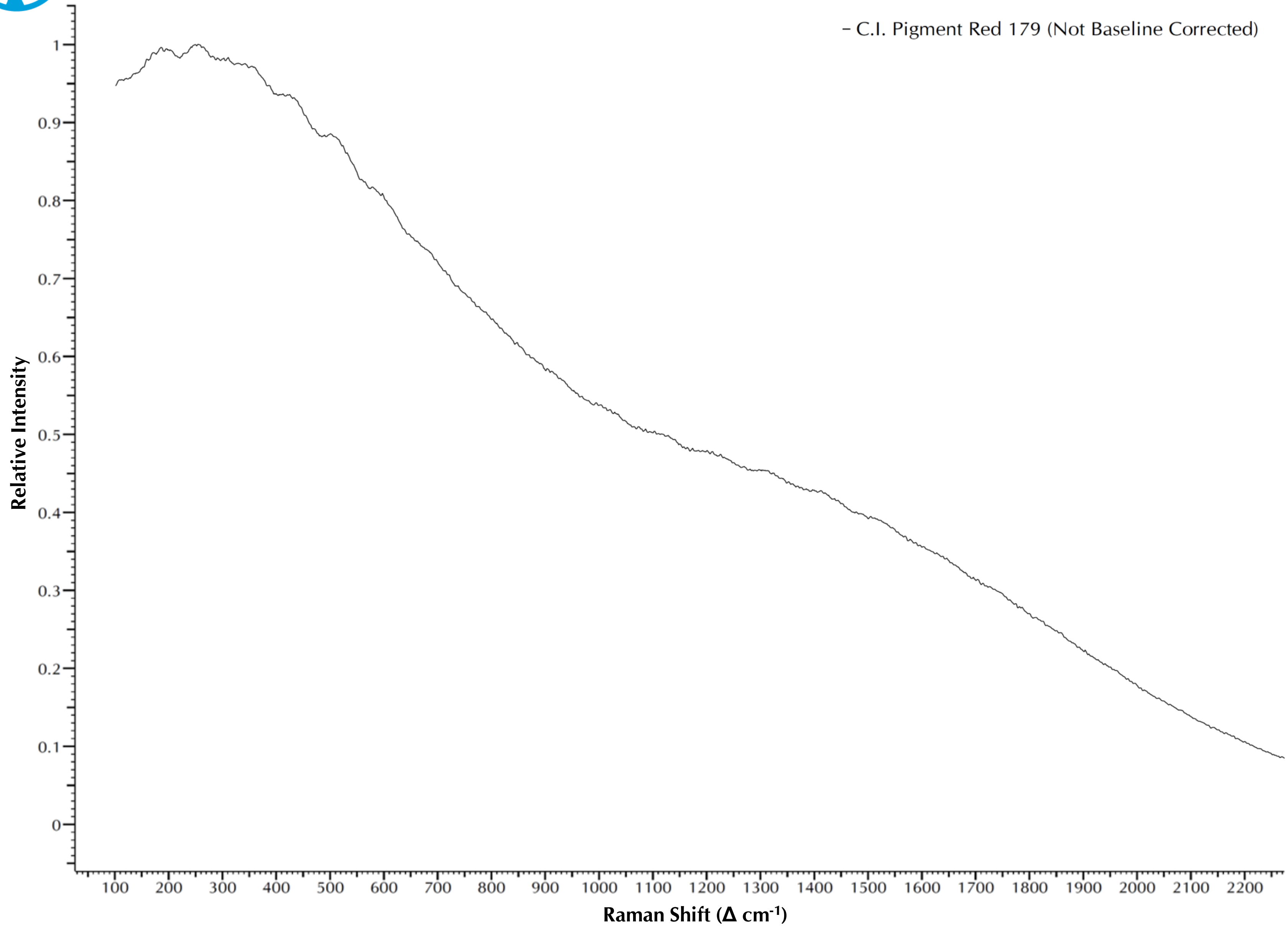
– C.I. Pigment Red 149
– C.I. Pigment Red 178
– C.I. Pigment Red 224
1304
1381
1709
1061
1148
1296
1374
1717
1307
1382
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Perylene

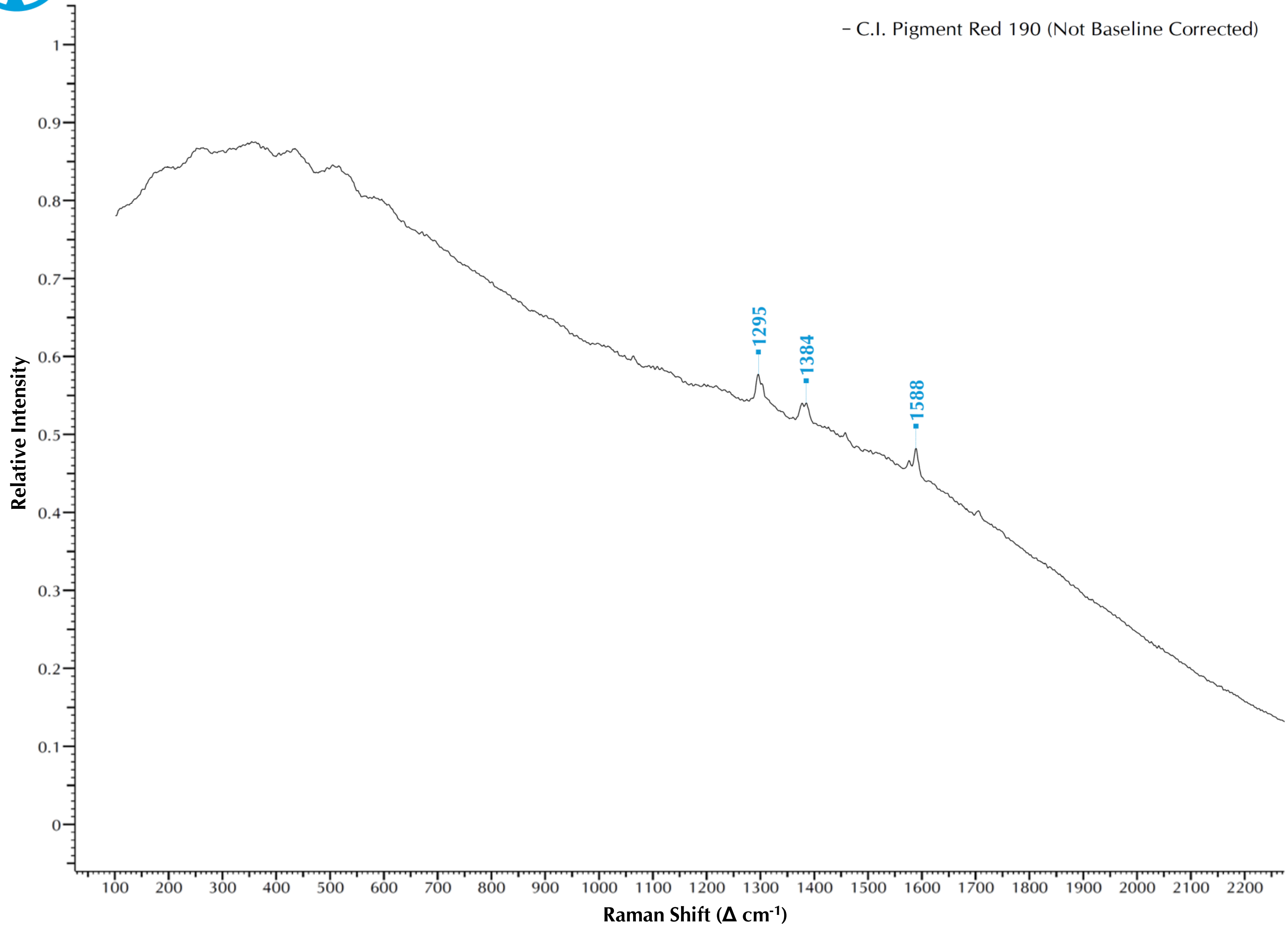


– C.I. Pigment Red 123
– C.I. Pigment Red 149
– C.I. Pigment Red 178
1297
1380
1061
1709
1304
1381
1709
1296
1374
1061
1148
1717
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200
Raman Shift (Δ cm-1)

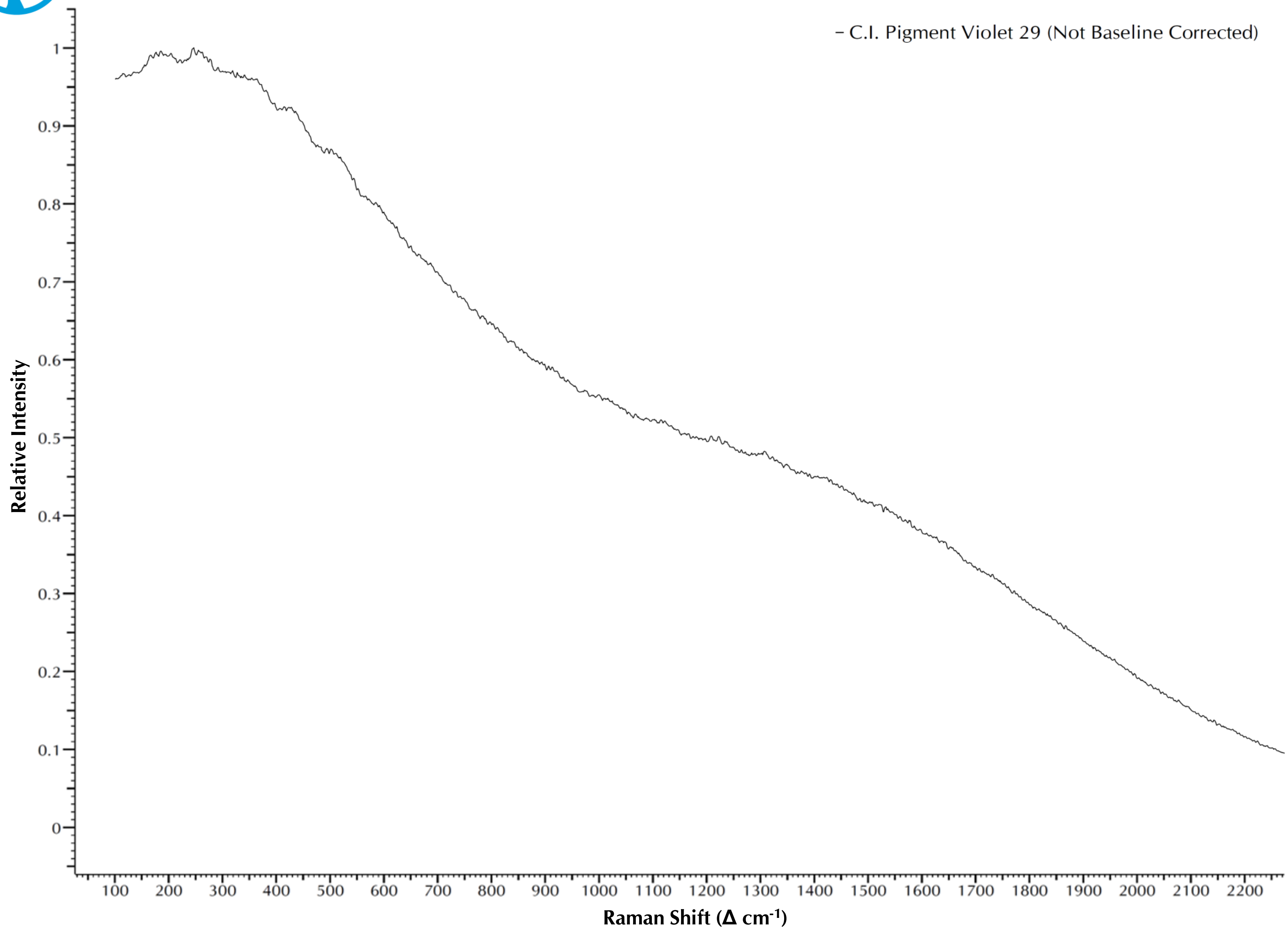
Perylene


– C.I. Pigment Red 179 (Not Baseline Corrected)
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Perylene

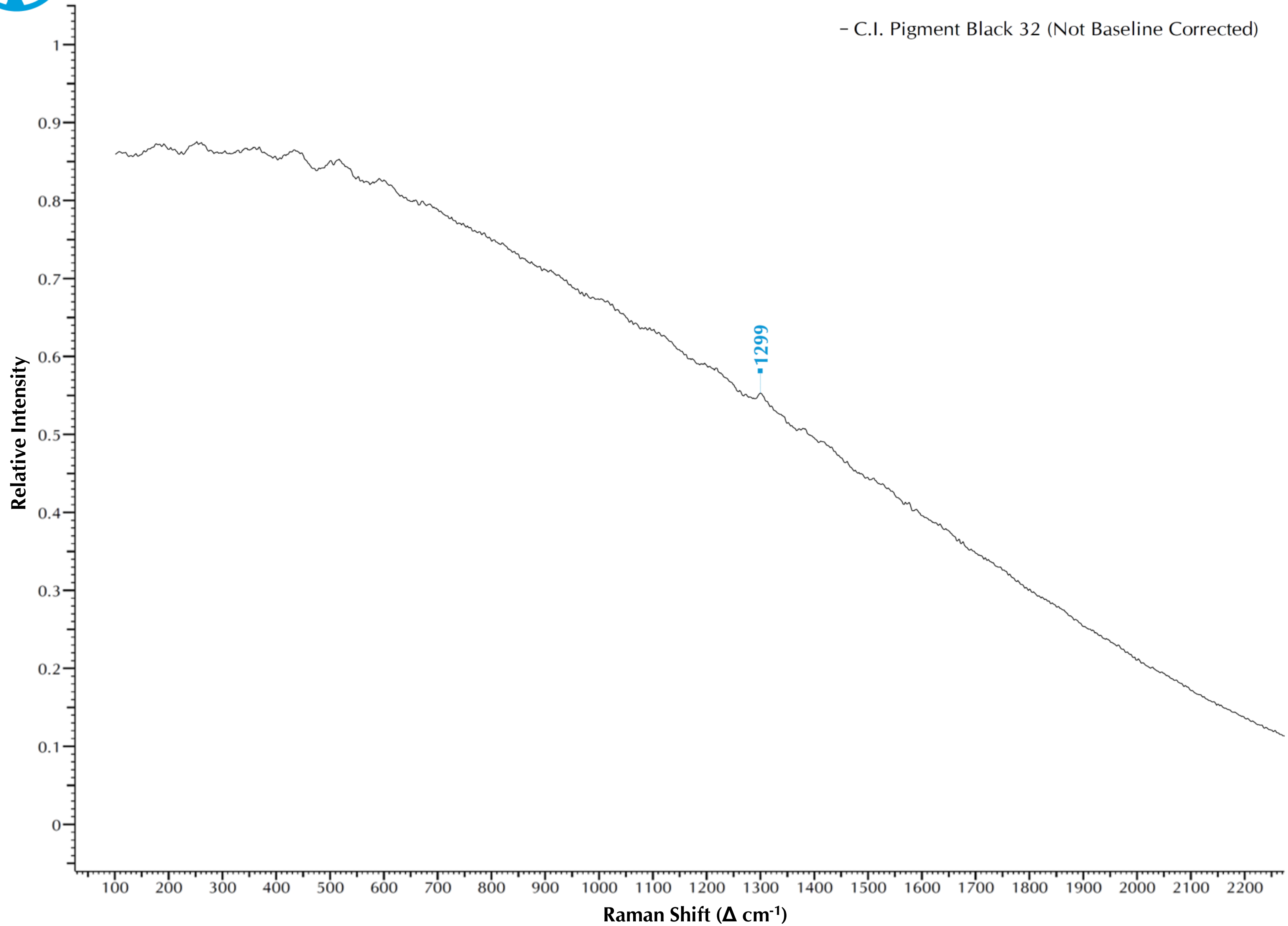

– C.I. Pigment Red 190 (Not Baseline Corrected)
1295
1384
1588
Relative Intensity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Perylene

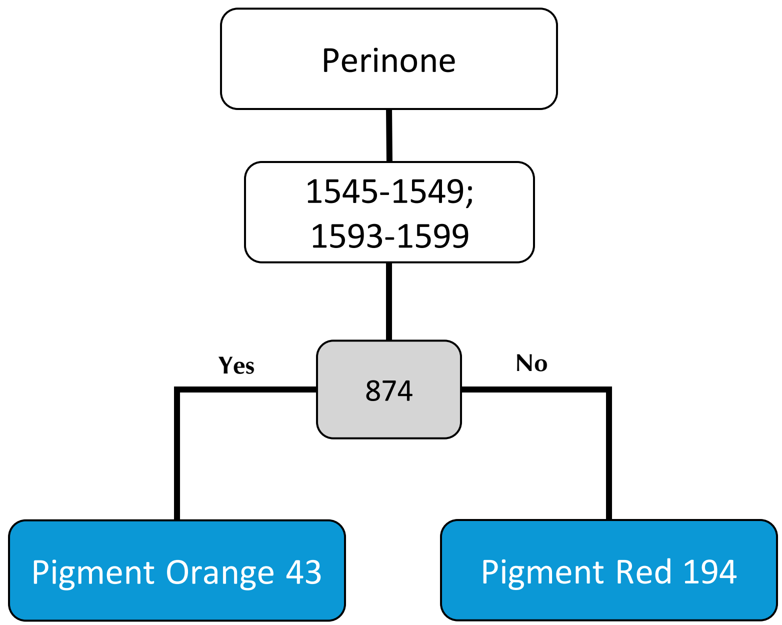


– C.I. Pigment Violet 29 (Not Baseline Corrected)
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200
Raman Shift (Δ cm-1)

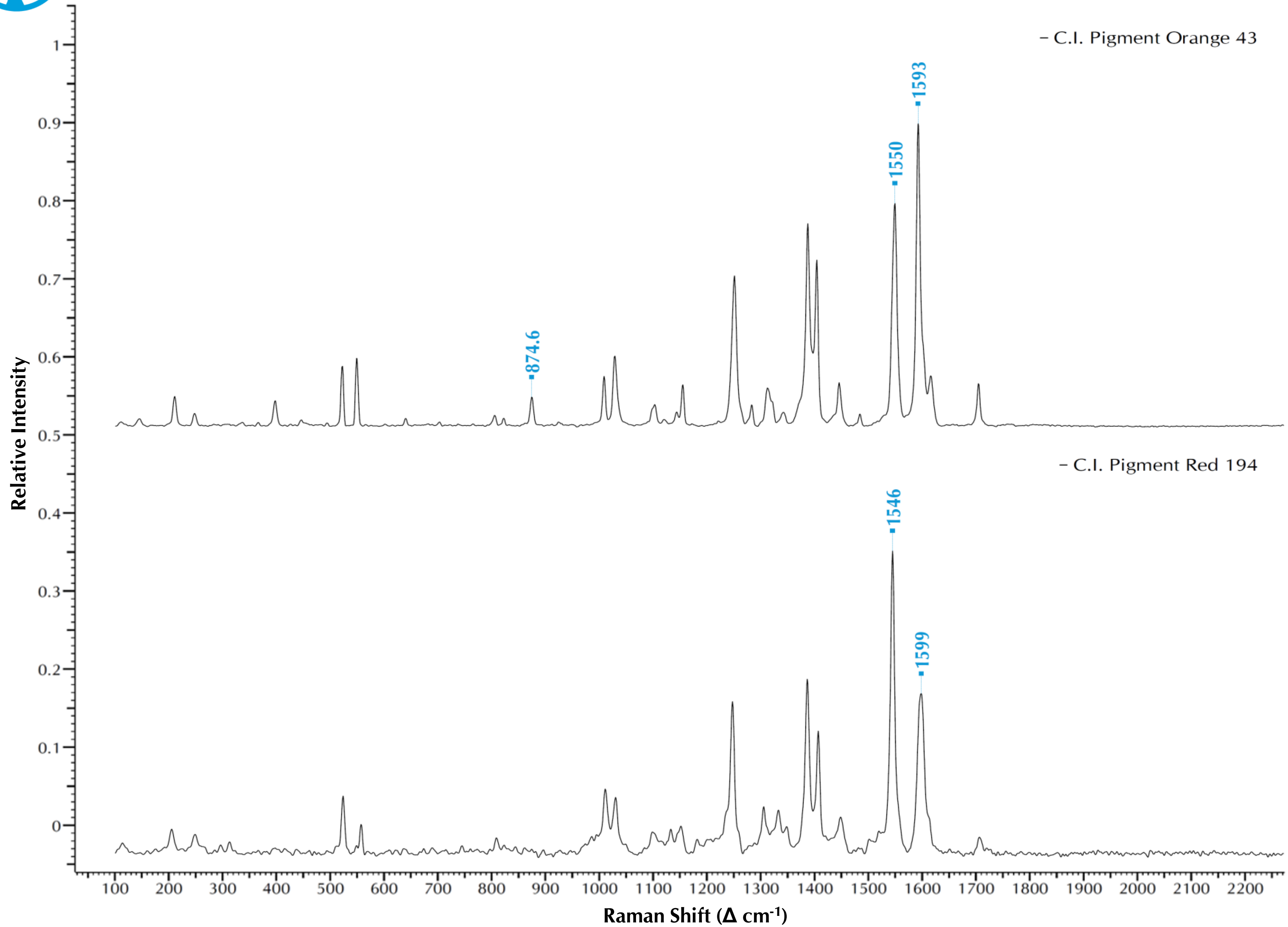
Perylene


– C.I. Pigment Black 32 (Not Baseline Corrected)
1299
Relative Intensity
Raman Shift (Δ cm-1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200

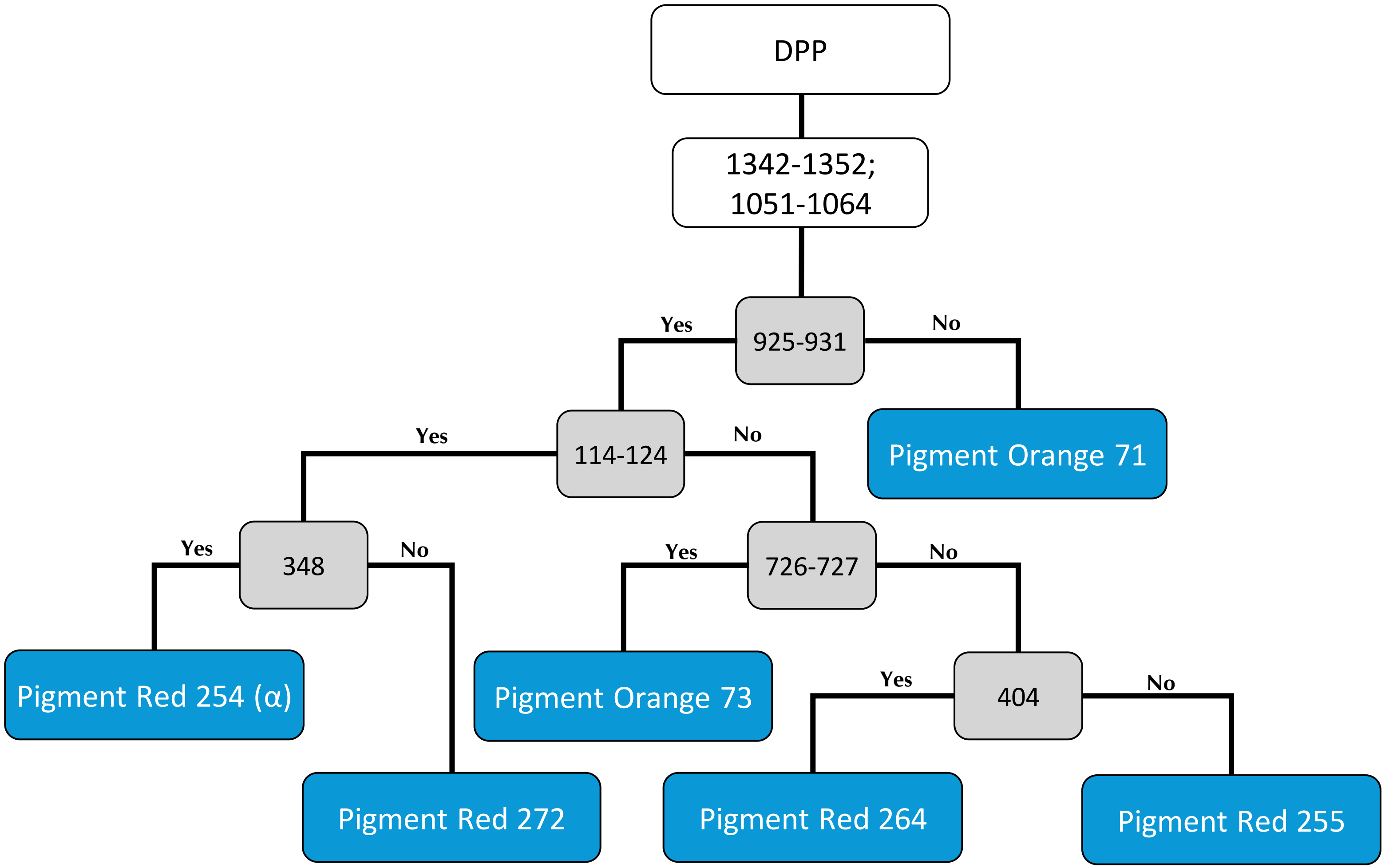
Perinone


Perinone
1545-1549;
1593-1599
874
Yes
No
Pigment Orange 43
Pigment Red 194

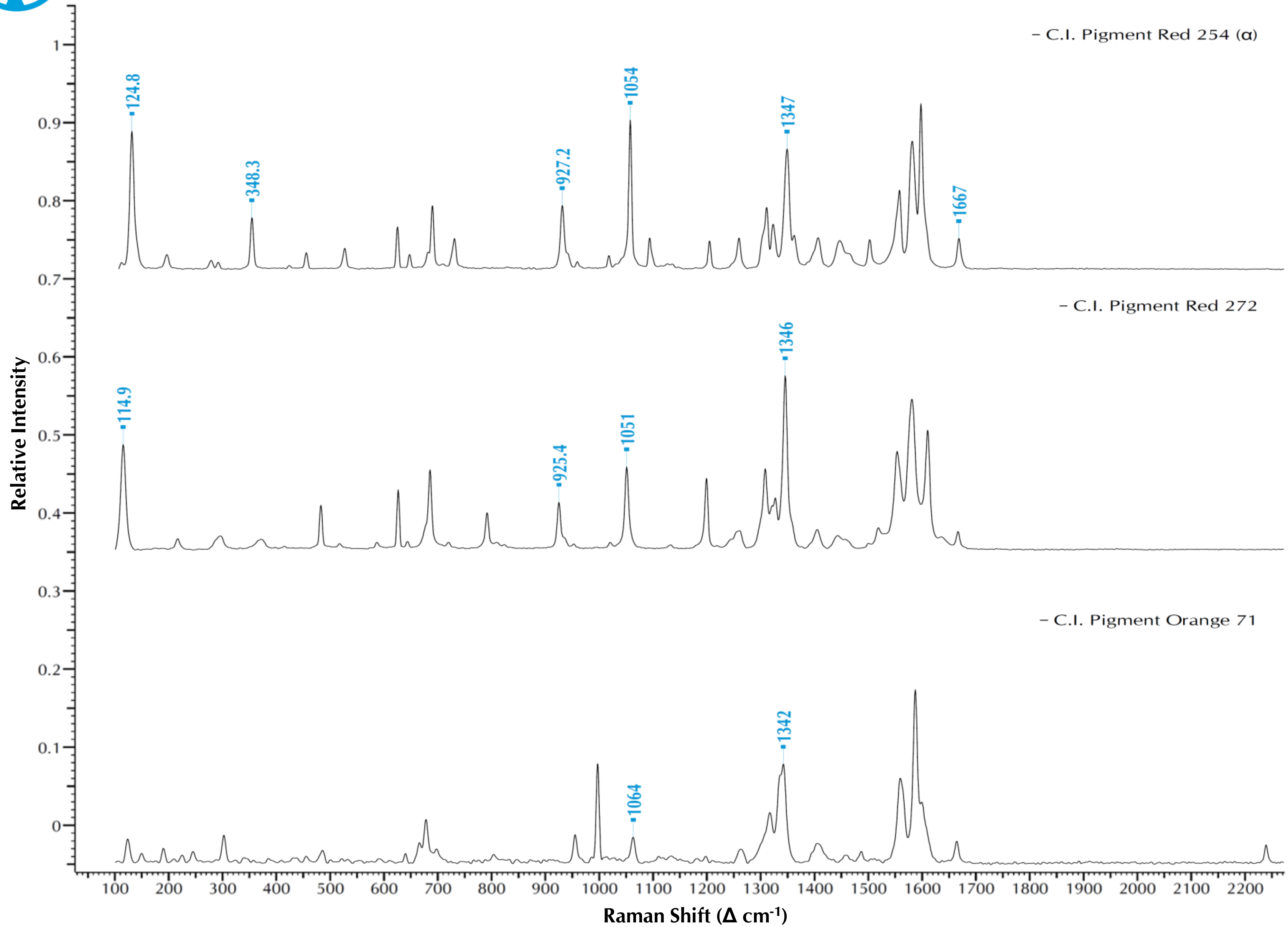
Perinone


C.I. Pigment Orange 43
C.I. Pigment Red 194
874.6
1550
1593
1546
1599
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

DPP

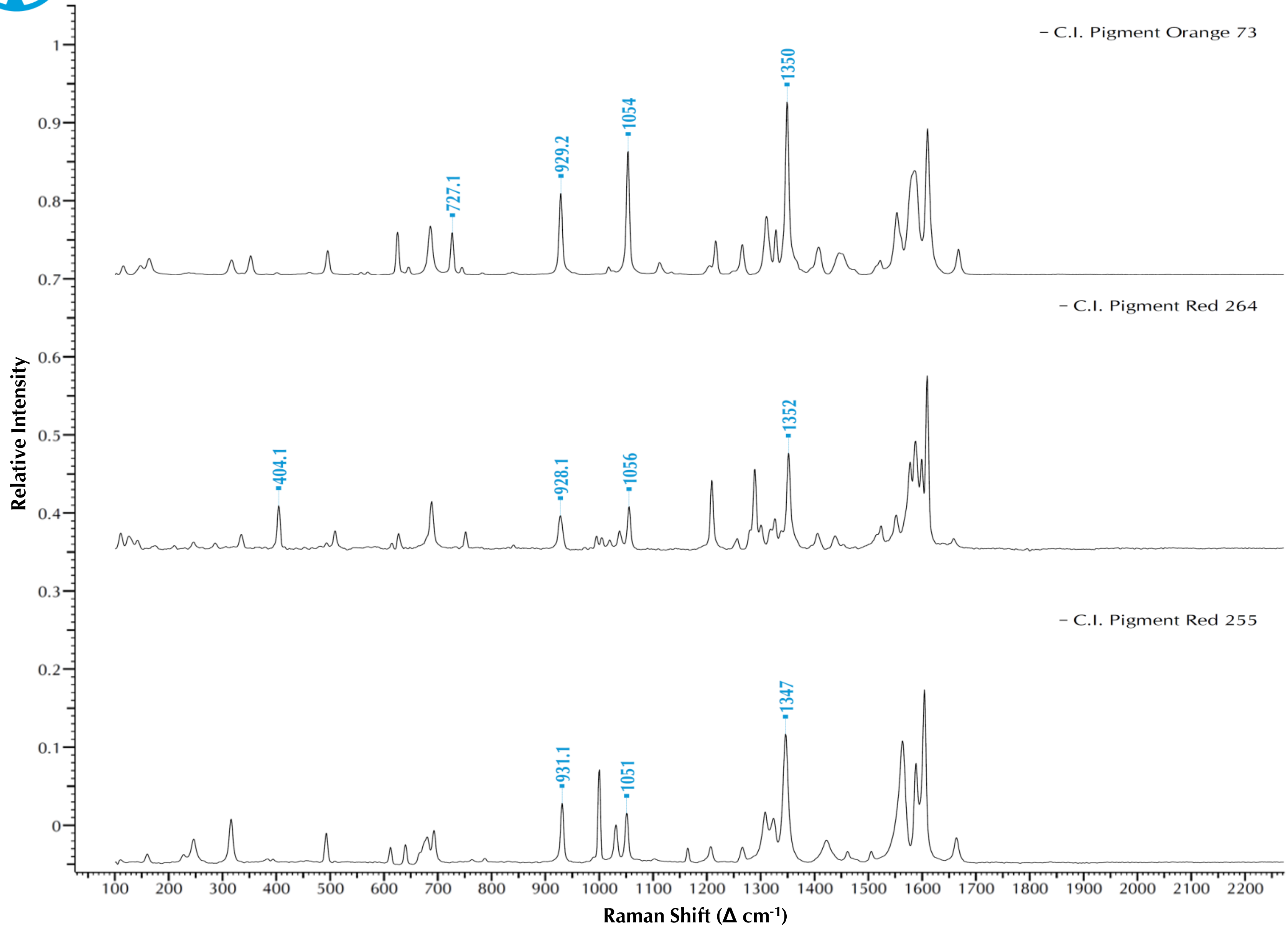

DPP
1342-1352;
1051-1064
925-931
Yes
No
114-124
Pigment Orange 71
Yes
No
348
726-727
Yes
No
Yes
No
Pigment Red 254 (α)
Pigment Orange 73
404
Yes
No
Pigment Red 272
Pigment Red 264
Pigment Red 255

DPP



Microtrace LLC

DPP



Microtrace LLC

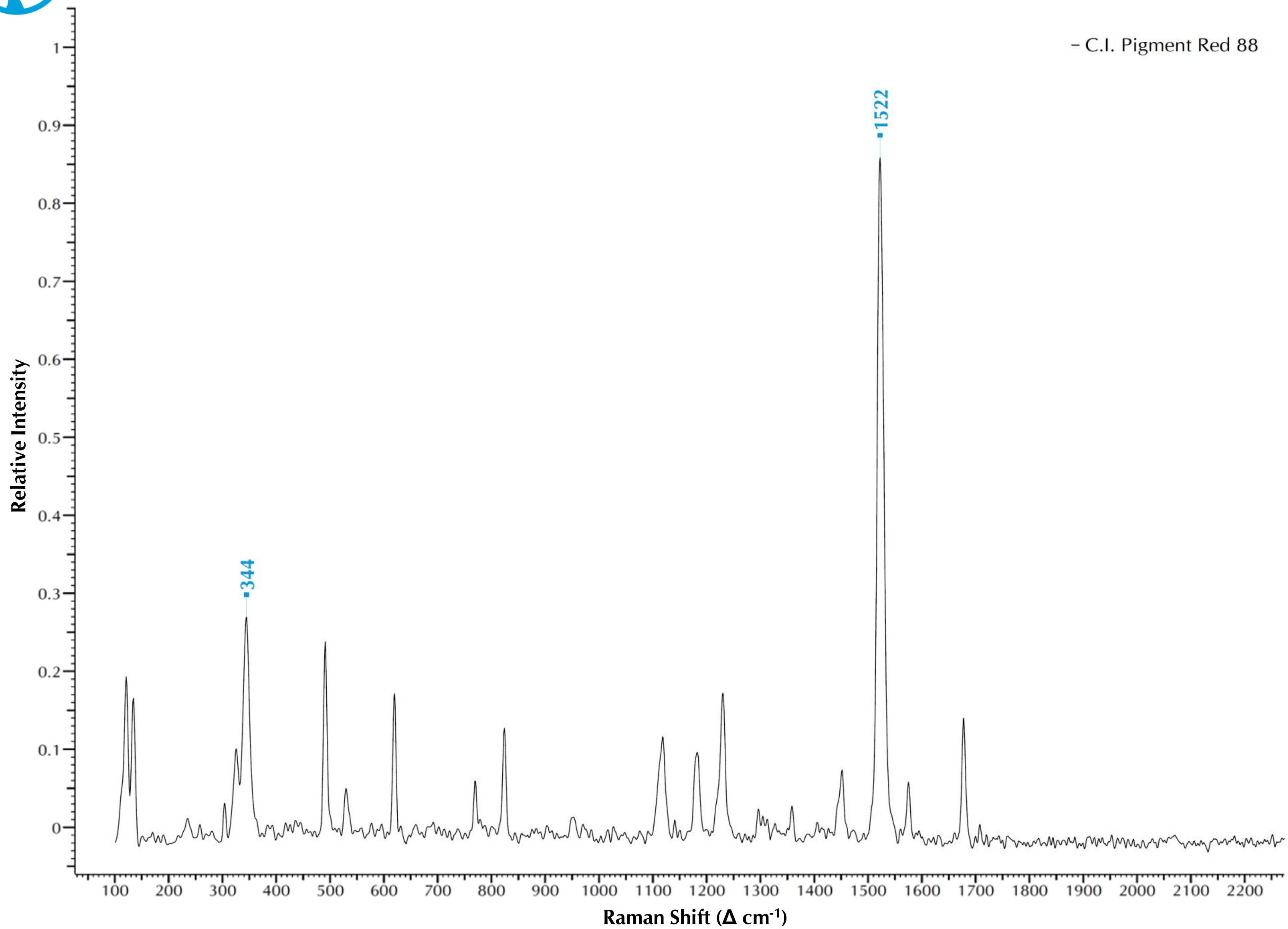
Thioindigo, substituted

Thioindigo, substituted

1522;
344

Pigment Red 88

Thioindigo, substituted



Microtrace LLC

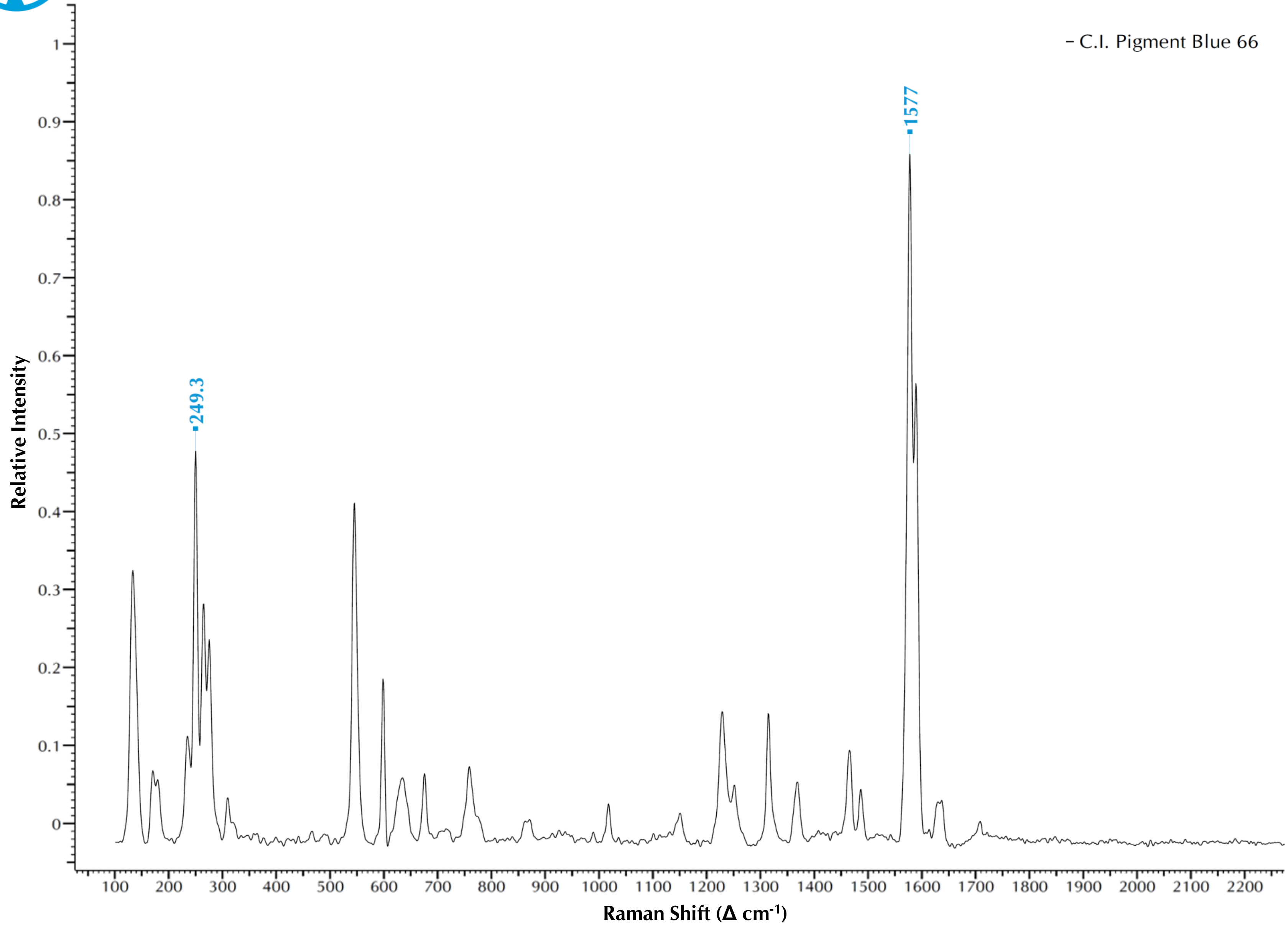
Thioindigo, unsubstituted

Thioindigo, unsubstituted

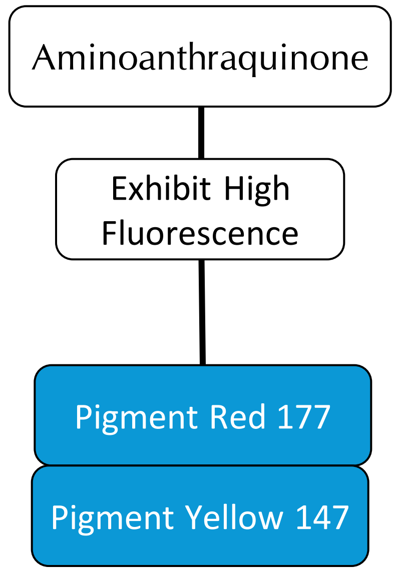
1577;
249

Pigment Blue 66

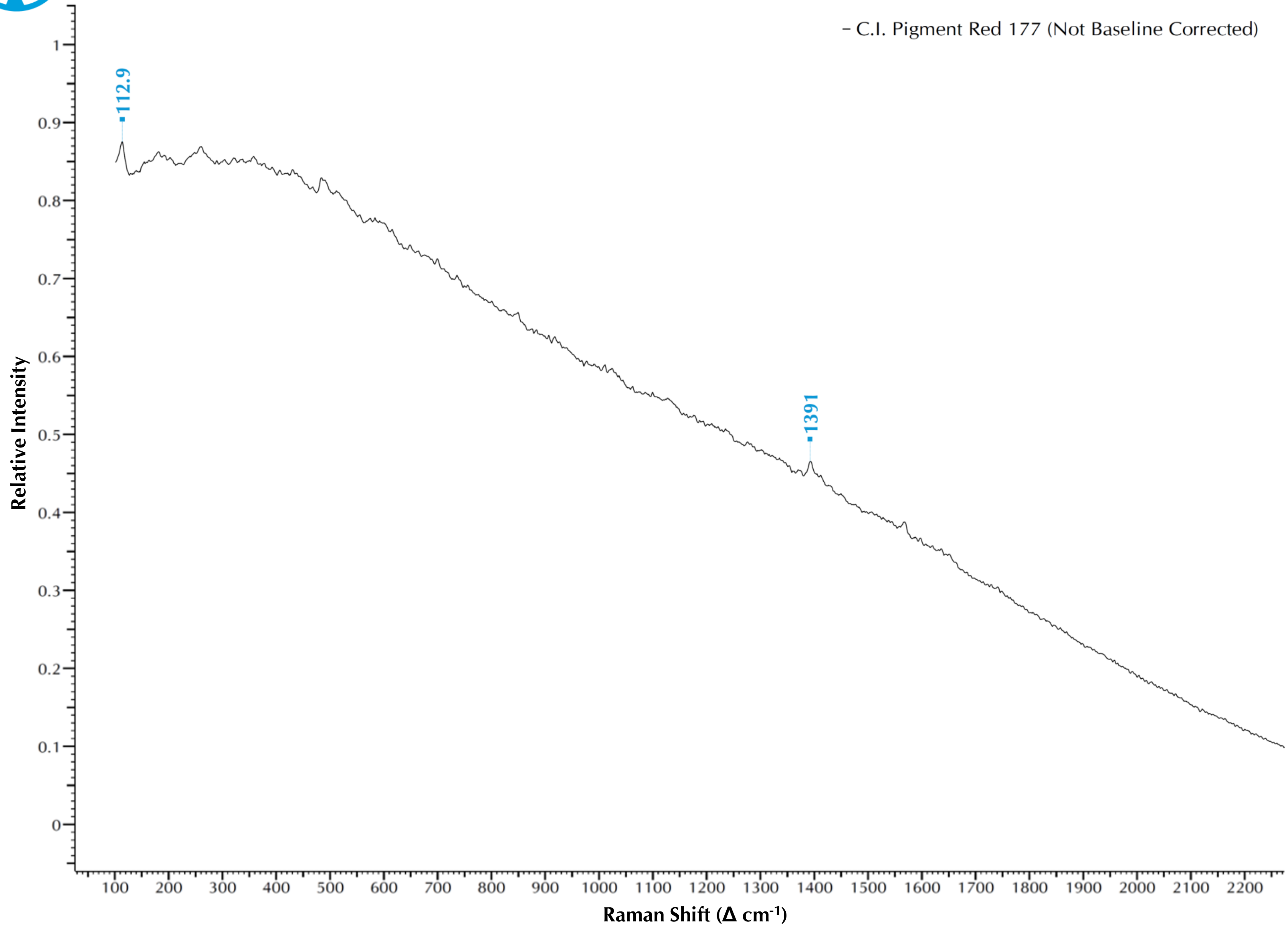
Thioindigo, unsubstituted



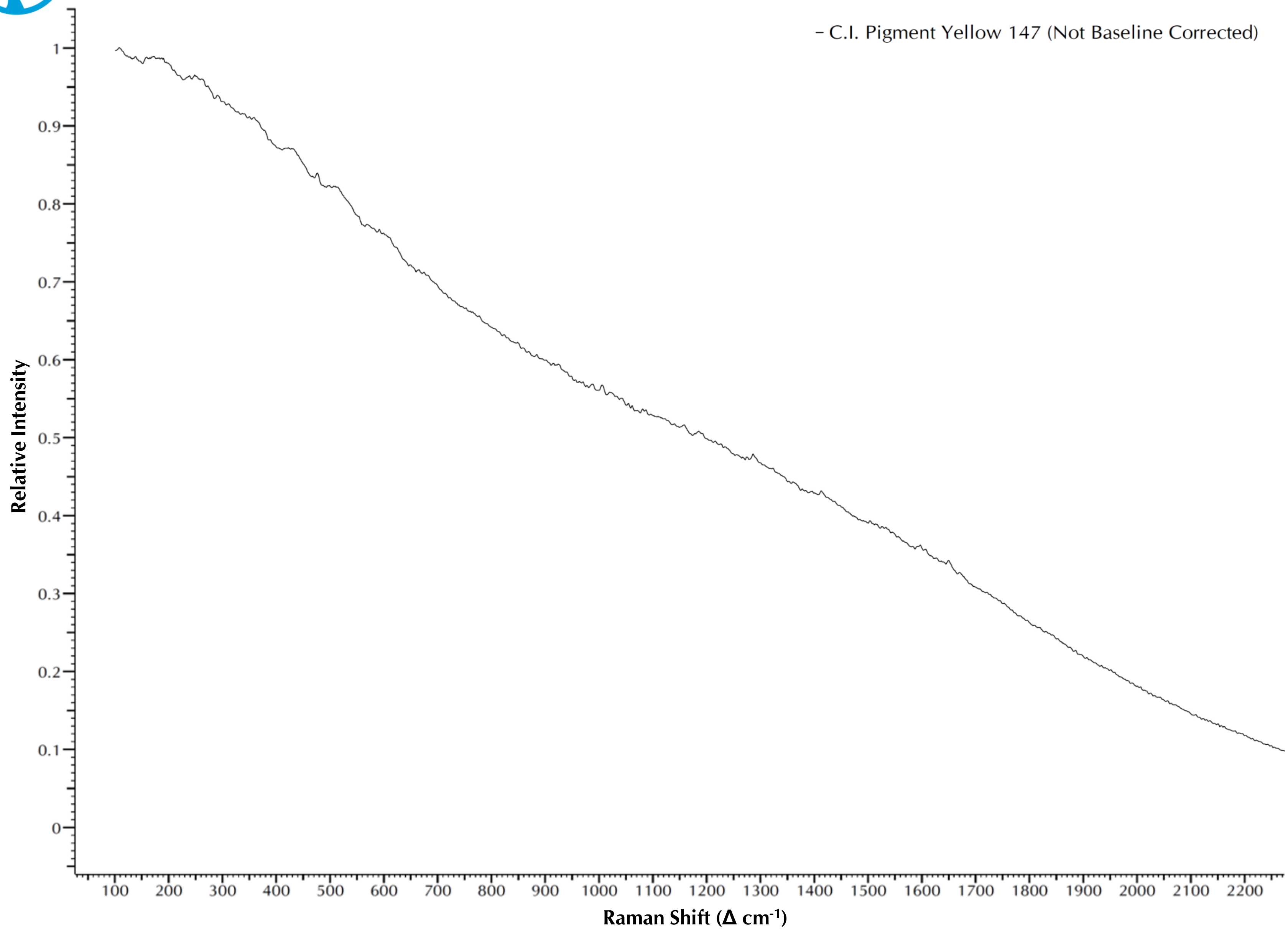
Aminoanthraquinone



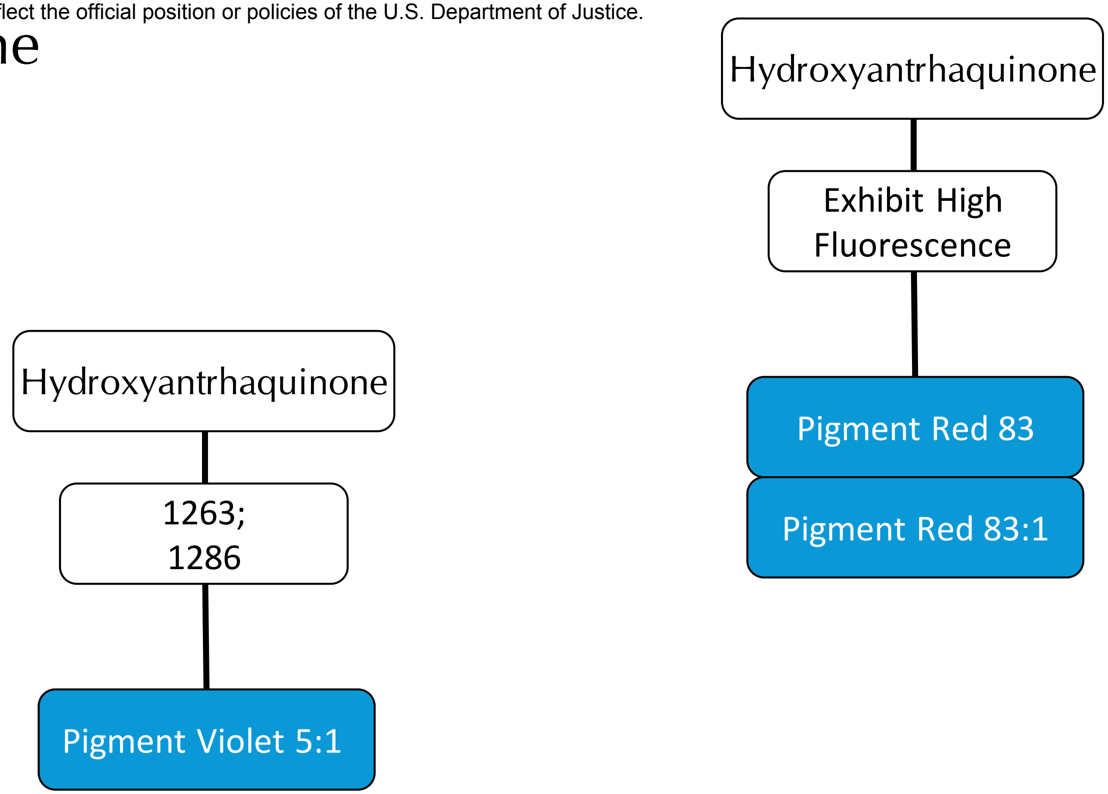
Aminoanthraquinone



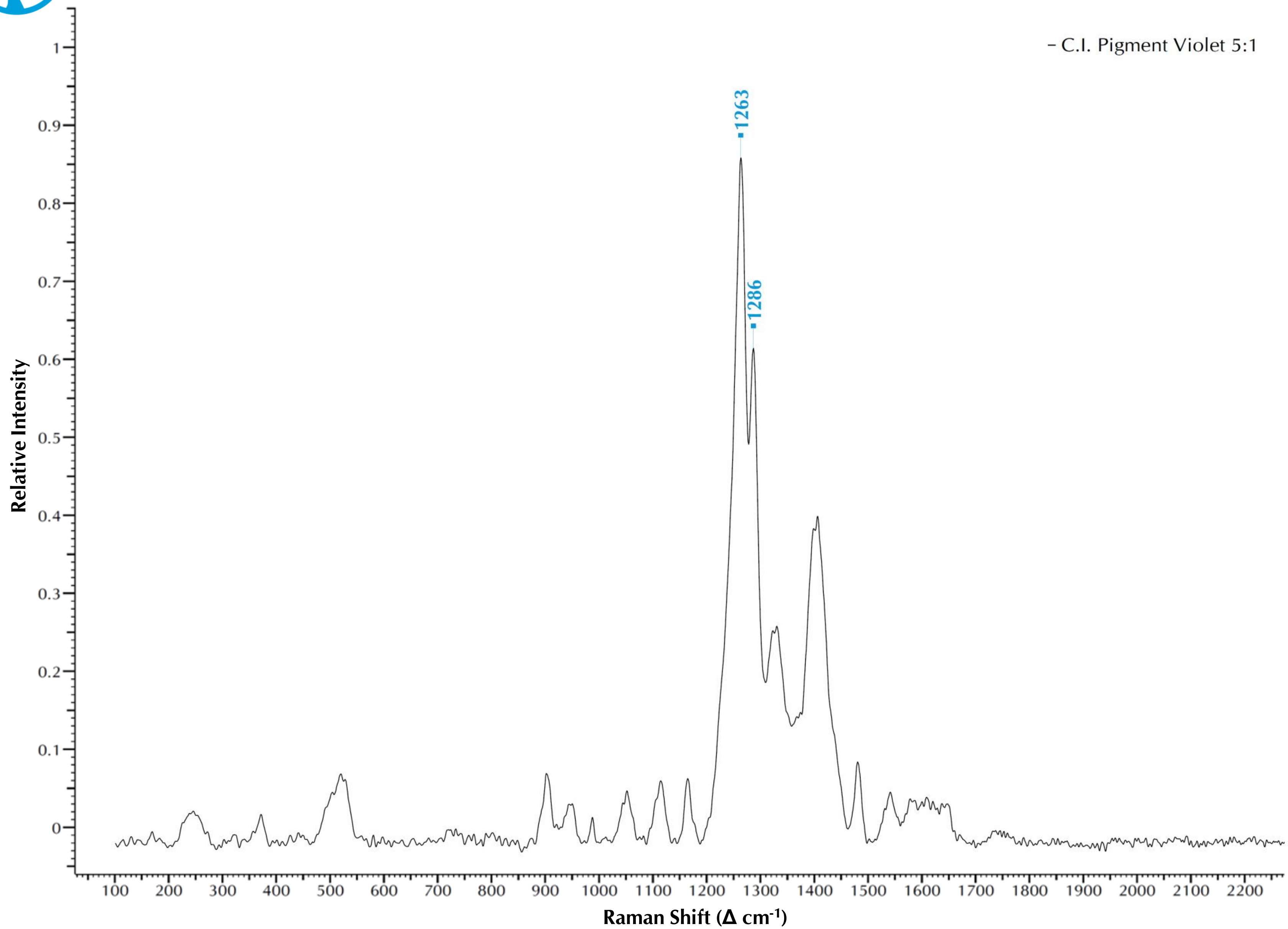
Aminoanthraquinone



Hydroxyantrhaquinone

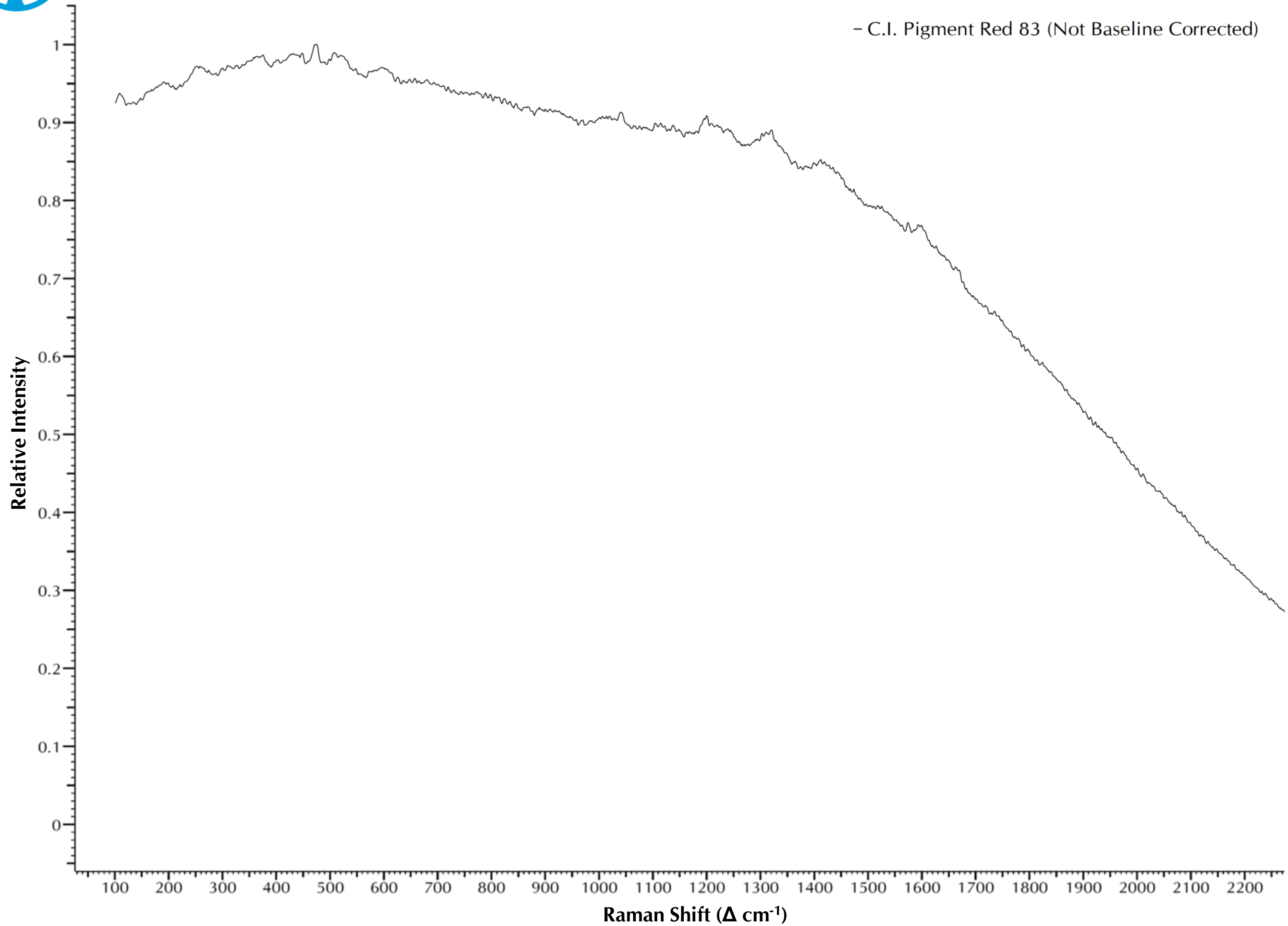


Hydroxyantrhaquinone

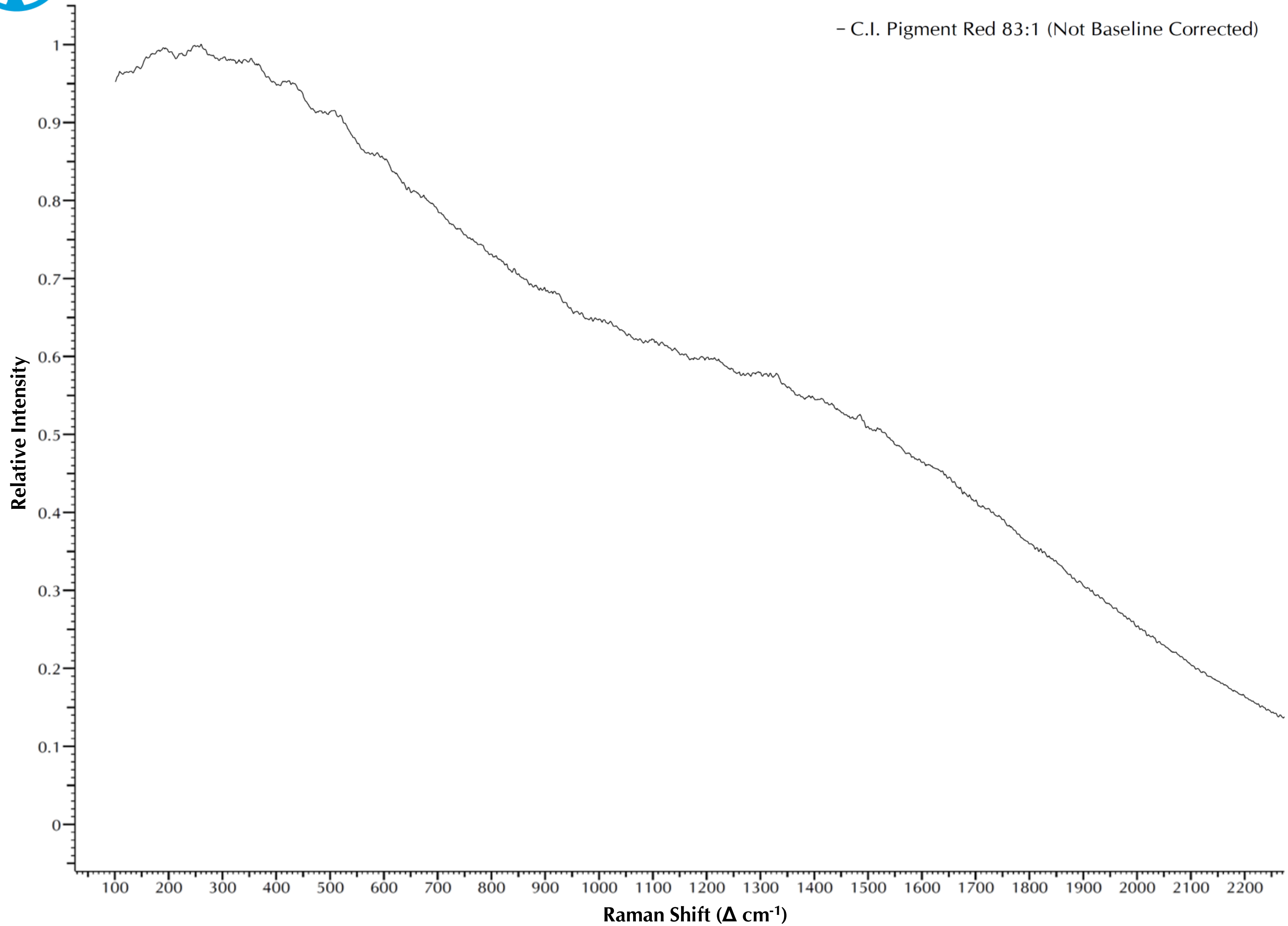


Microtrace LLC

Hydroxyantrhaquinone



Hydroxyantrhaquinone



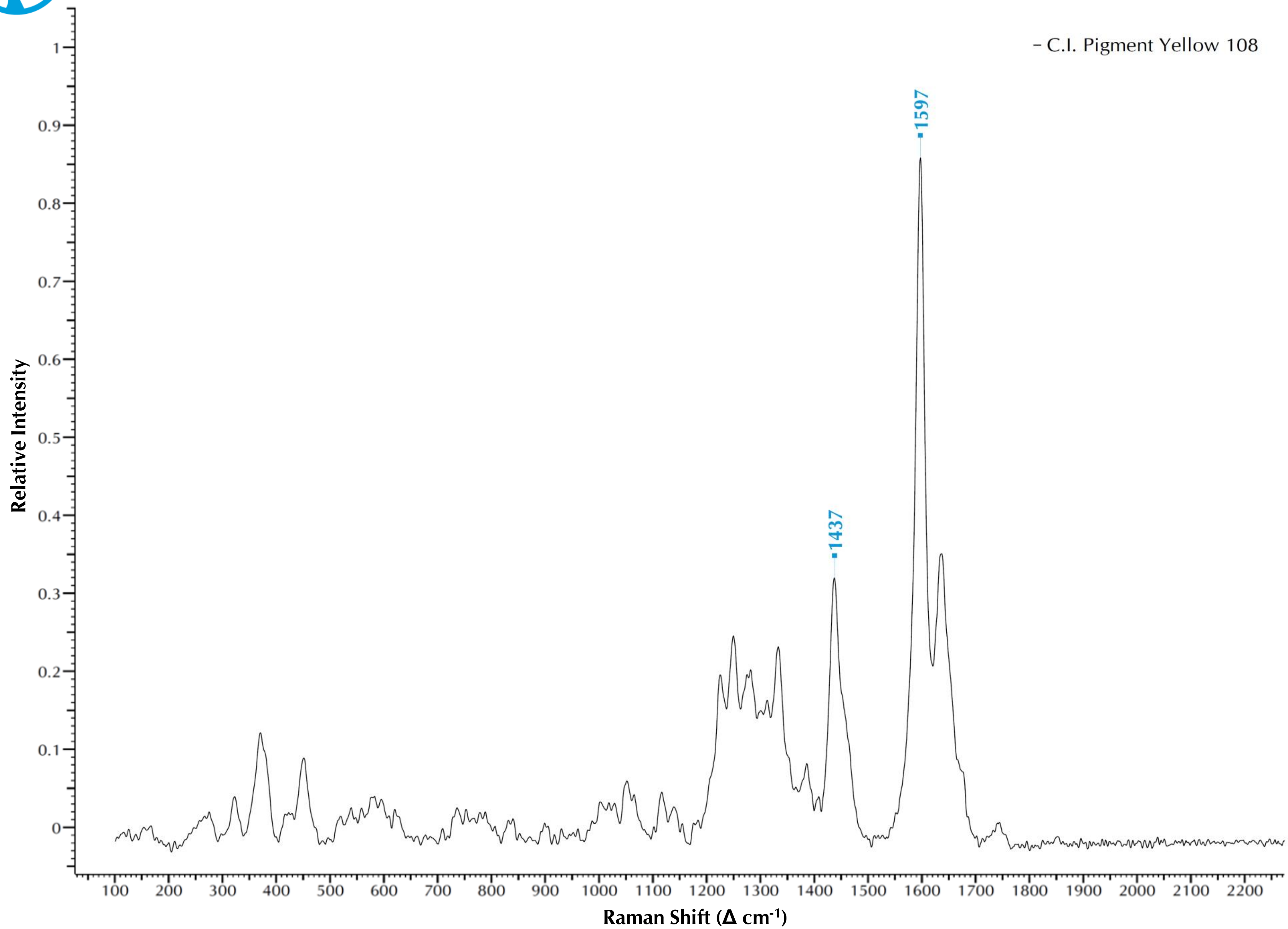
Anthrapyrimidine

Anthrapryimidine

1597;
1437

Pigment Yellow 108

Anthrapyrimidine



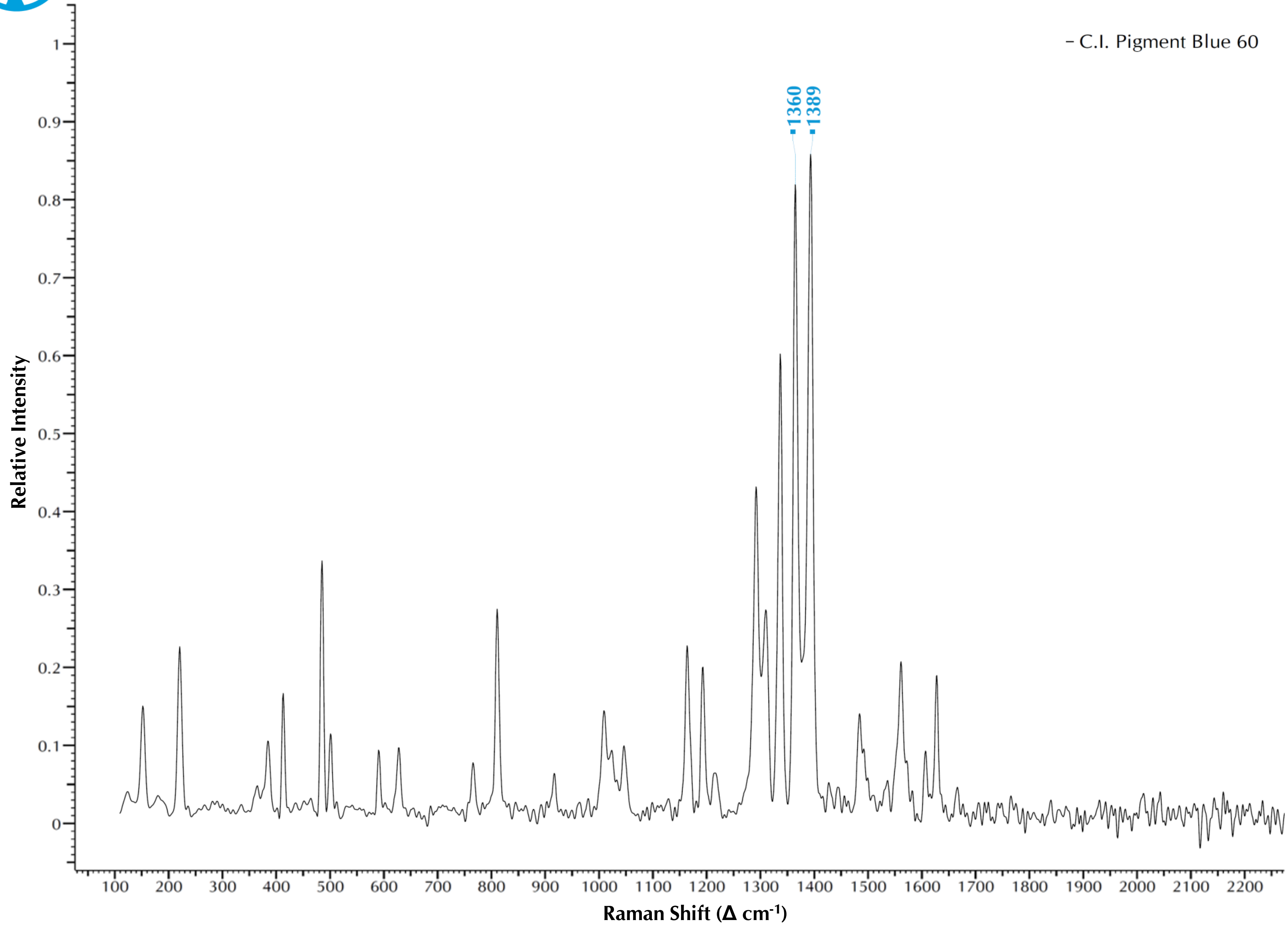
Indanthrone

Indanthrone

1389;
1360

Pigment Blue 60

Indanthrone



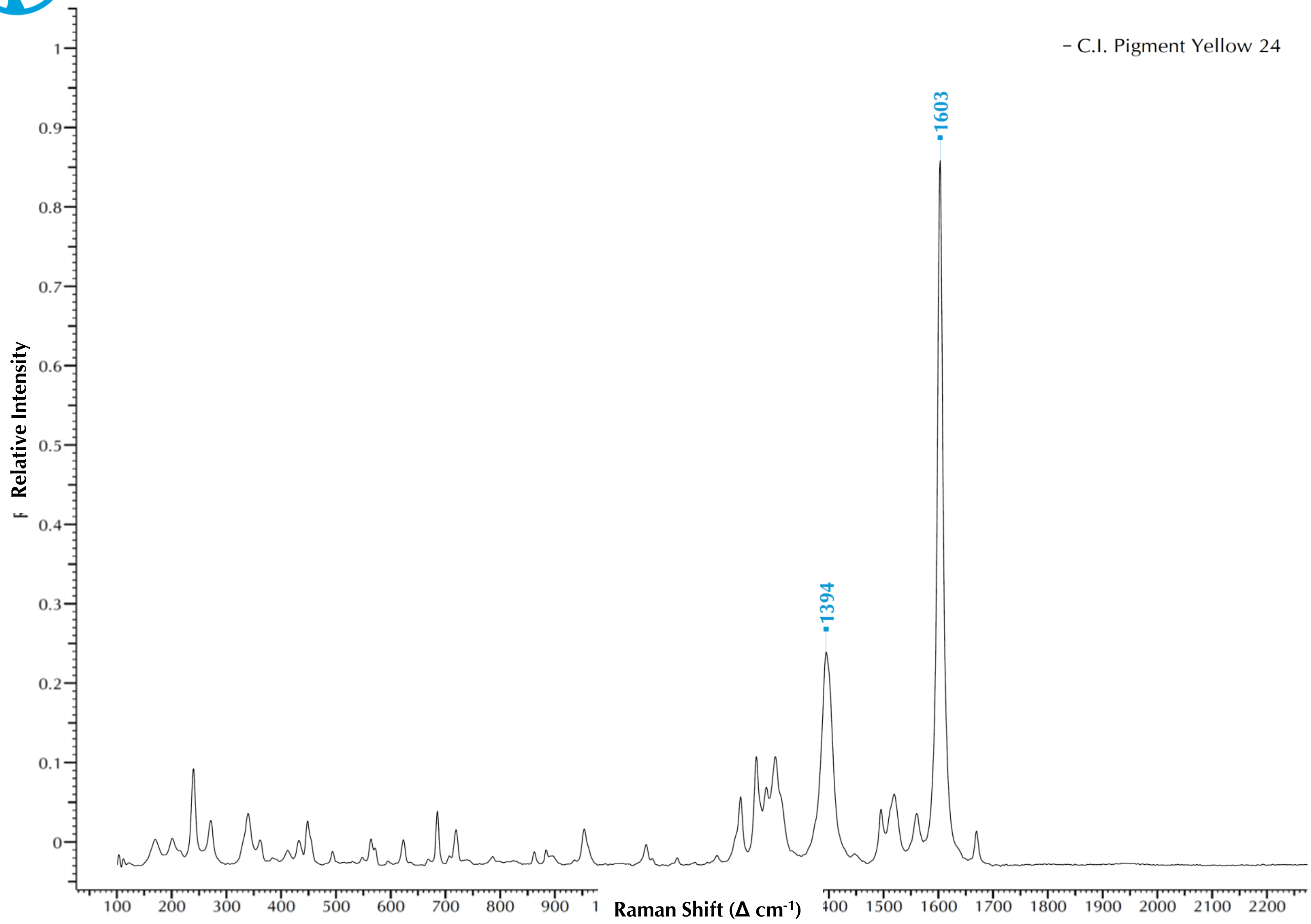
Flavanthrone

Flavanthrone

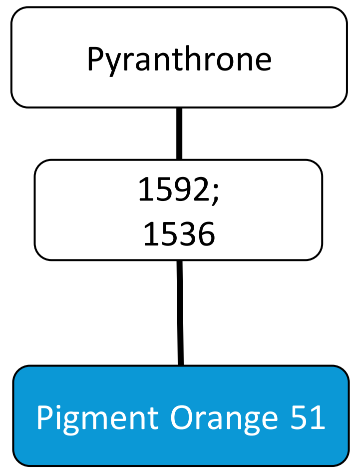
1602-1603;
1394

Pigment Yellow 24

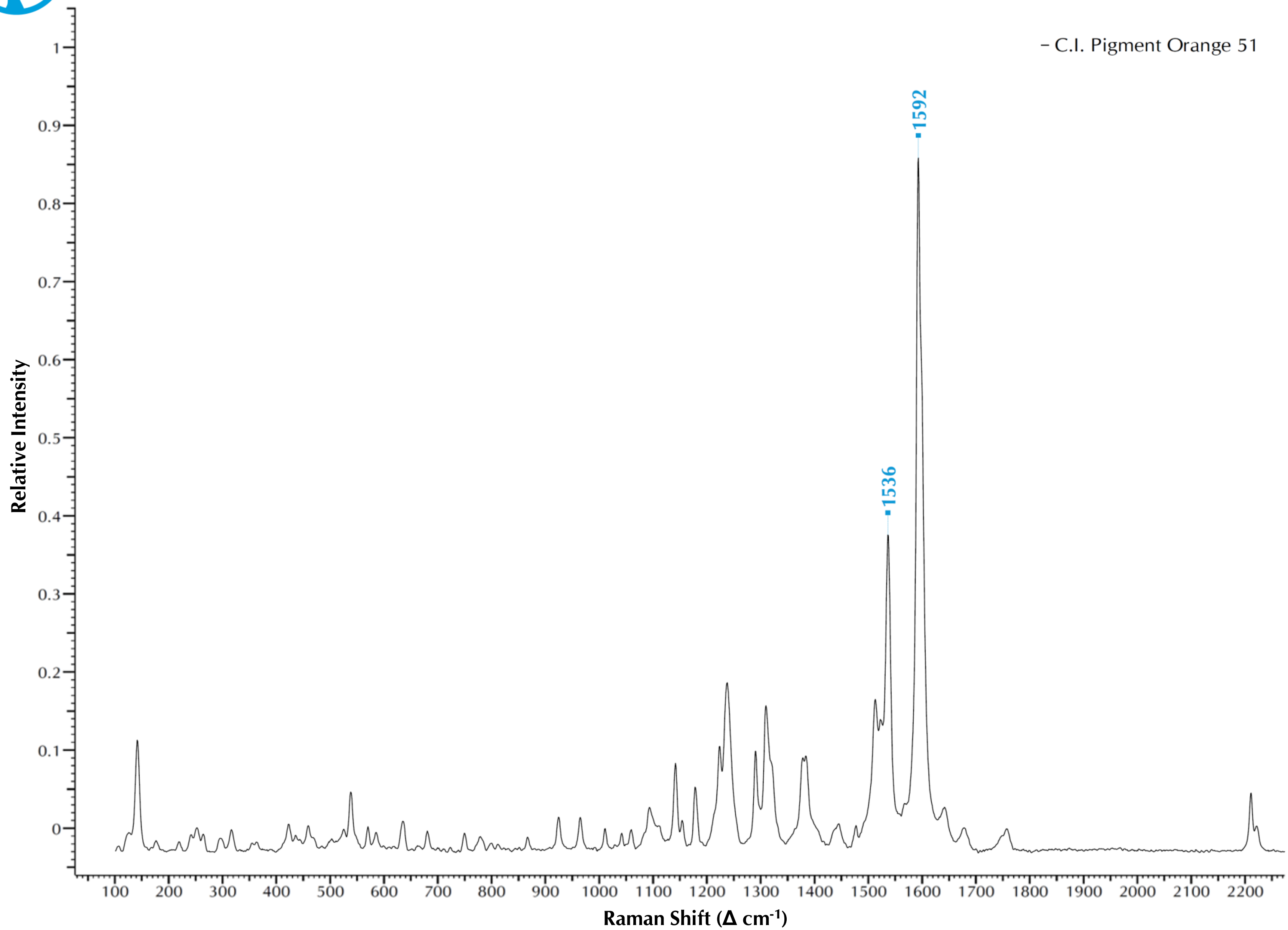
Flavanthrone



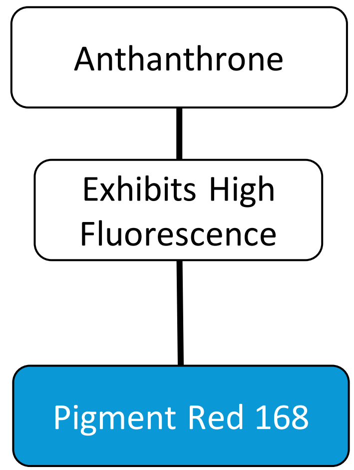
Pyranthrone



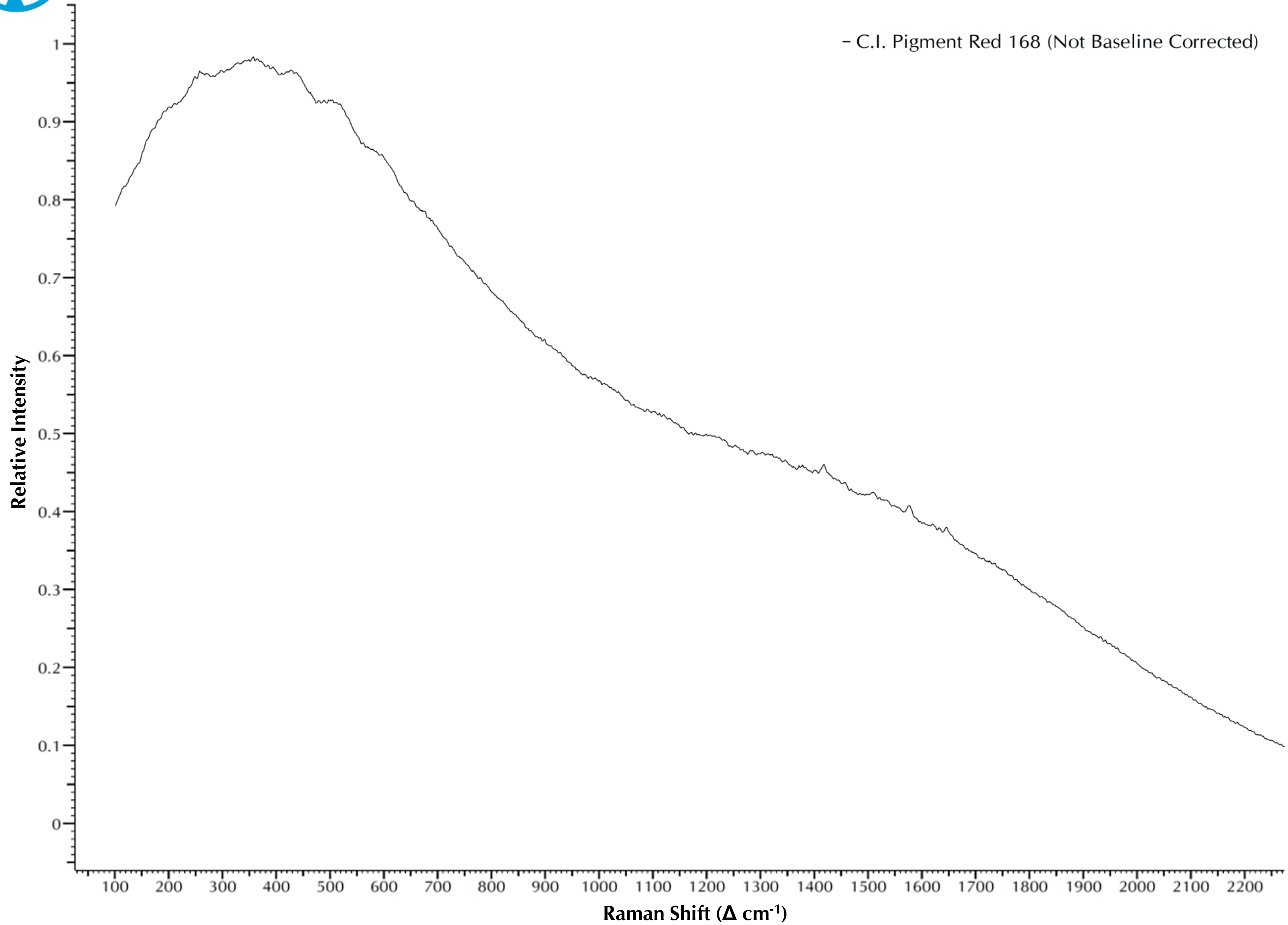
Pyranthrone



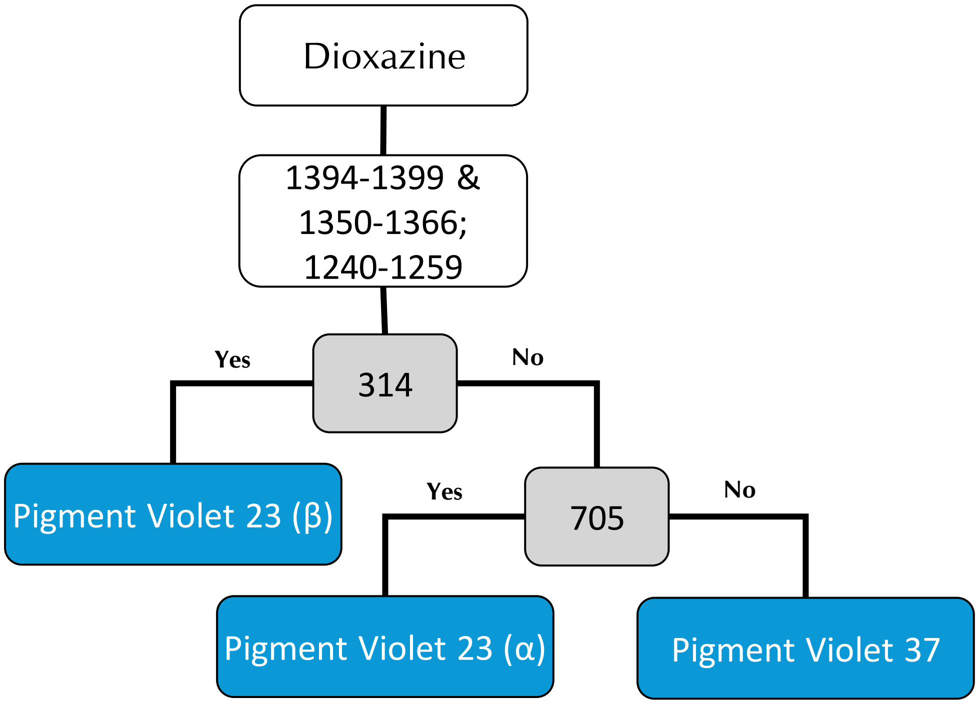
Anthanthrone



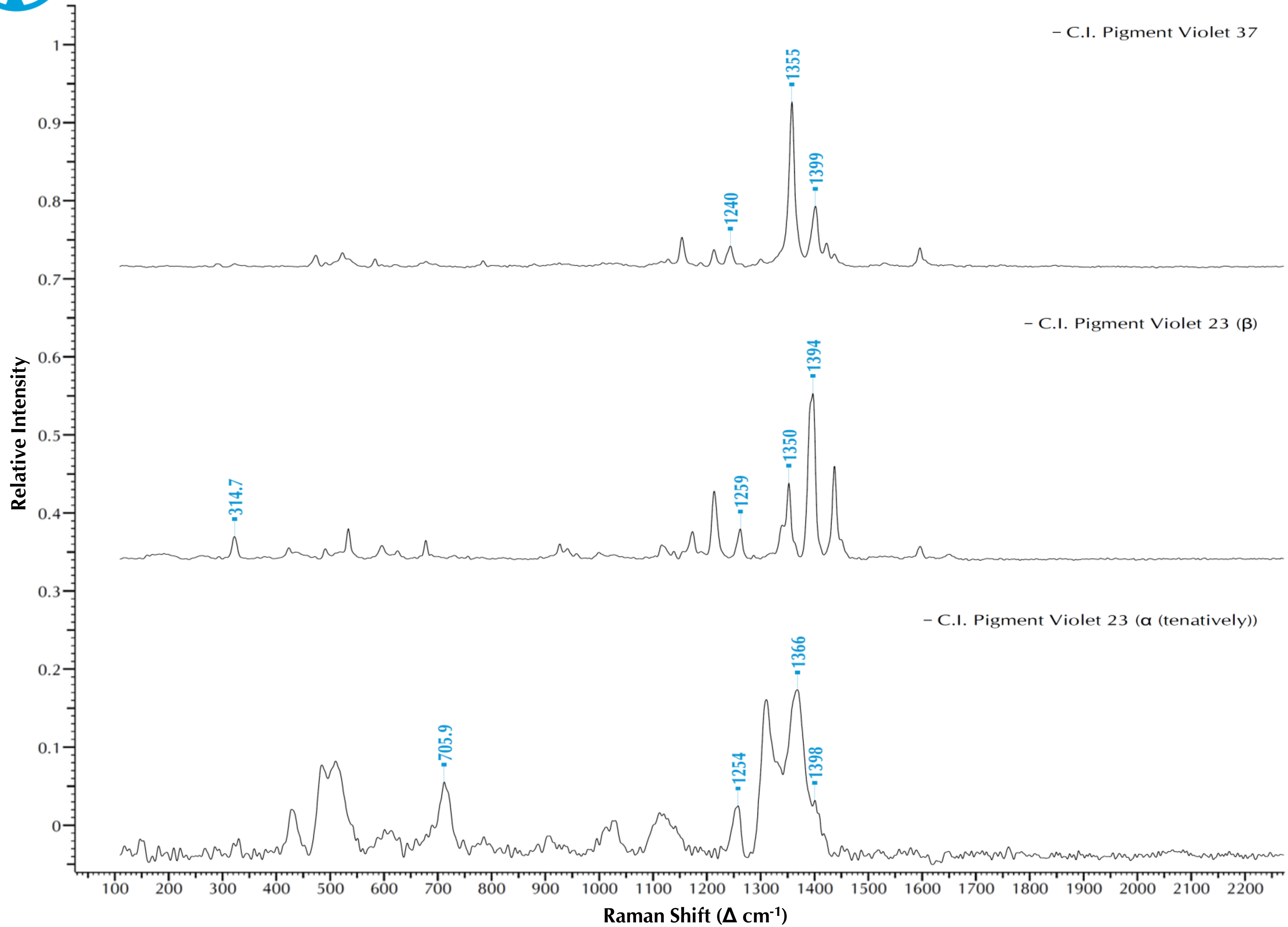
Anthanthrone



Dioxazine


Dioxazine
1394-1399 &
1350-1366;
1240-1259
314
Yes
No
Pigment Violet 23 (β)
705
Yes
No
Pigment Violet 23 (α)
Pigment Violet 37

Dioxazine



– C.I. Pigment Violet 37
1355
1399
1240
– C.I. Pigment Violet 23 (β)
1394
1350
1259
314.7
– C.I. Pigment Violet 23 (α (tenatively))
1366
705.9
1254
1398
Relative Intensity
Raman Shift (Δ cm-1)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200

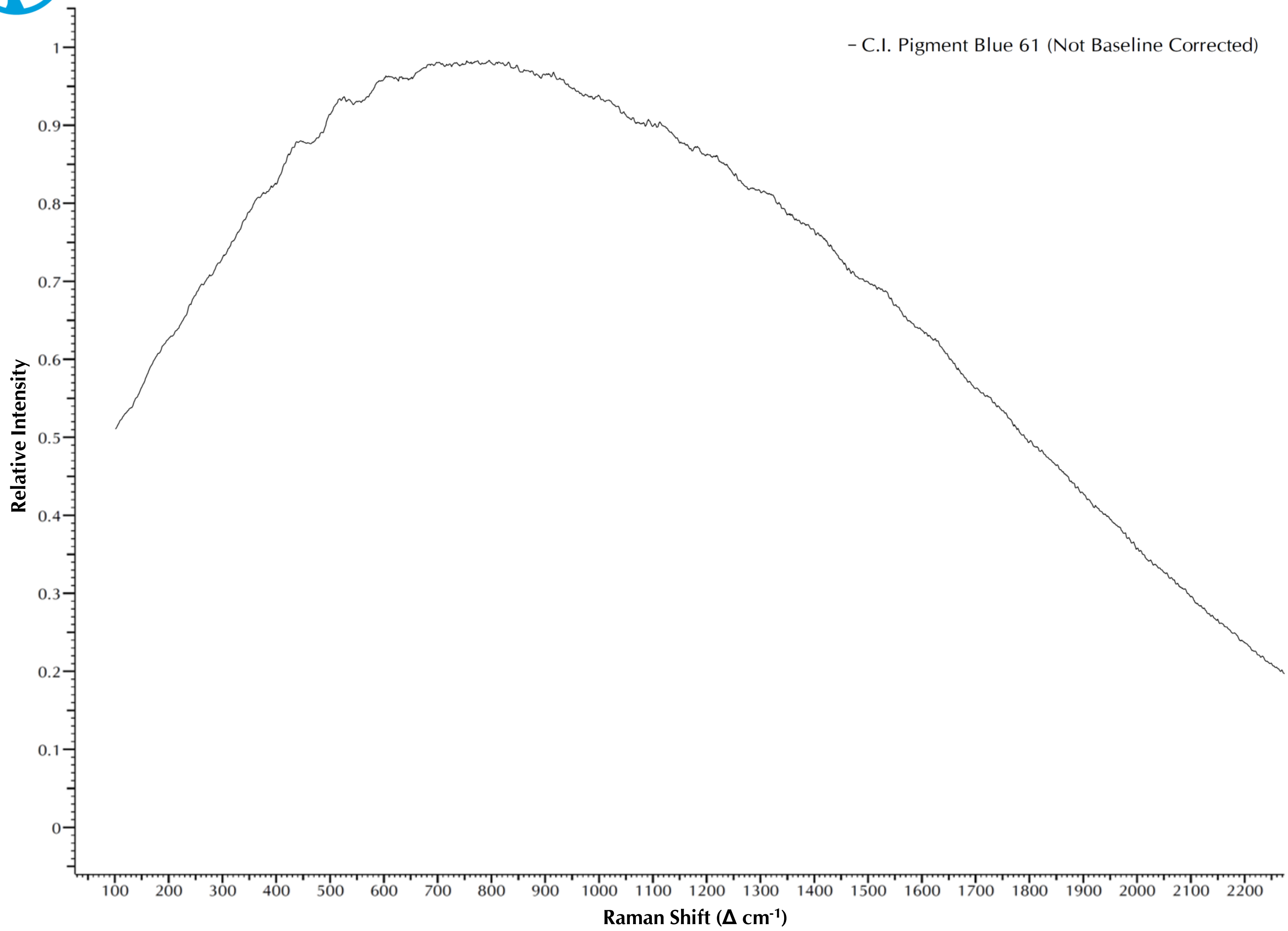
Triarylcarbonium – Inner Salt

Triarylcarbonium – Inner Salt

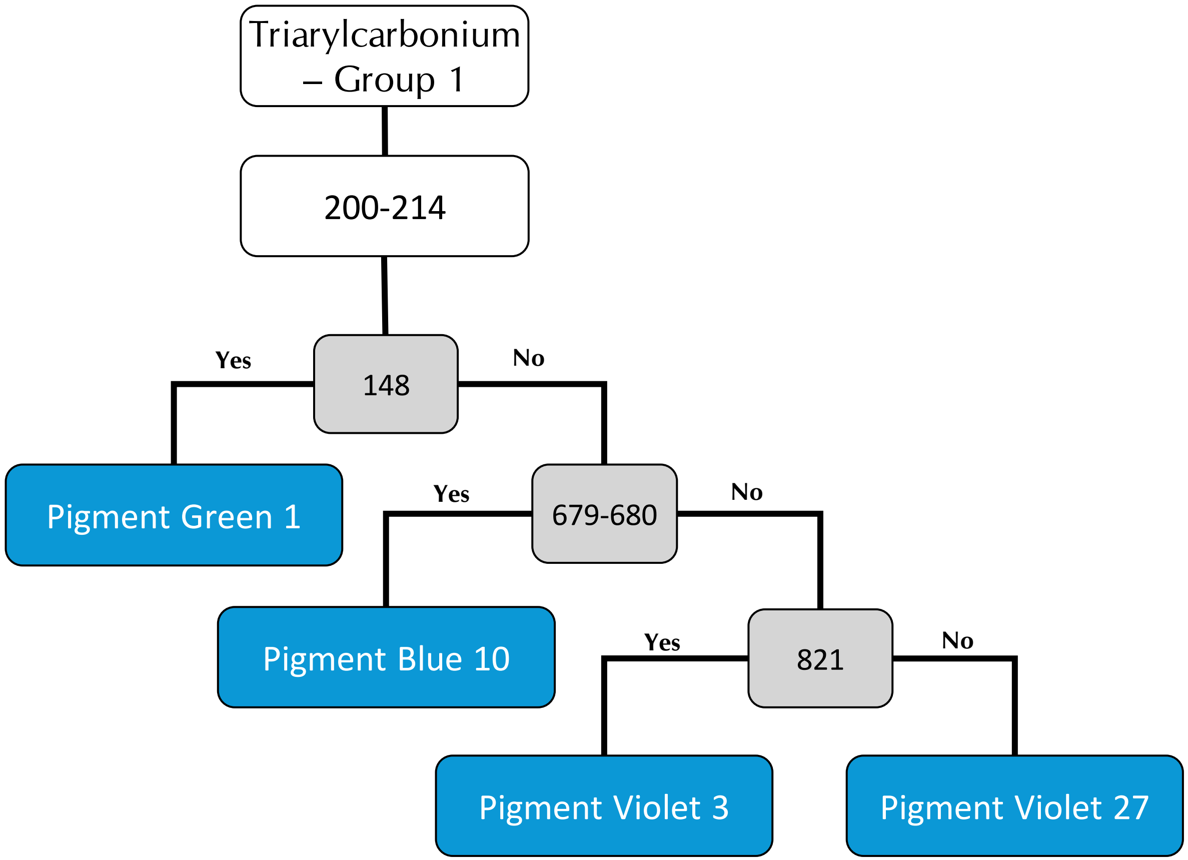
Exhibits High Fluorescence

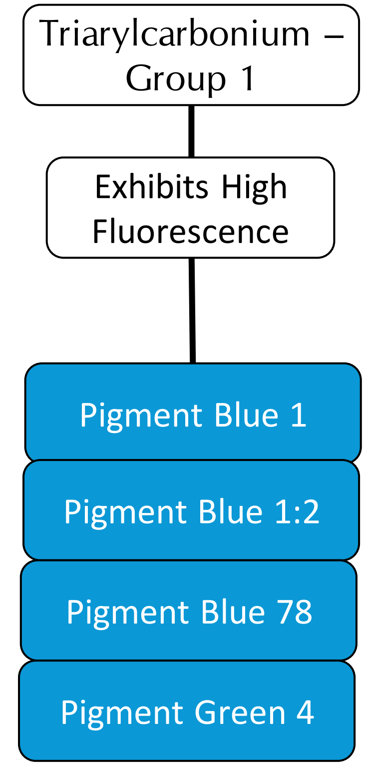
Pigment Blue 61

Triarylcarbonium – Inner Salt

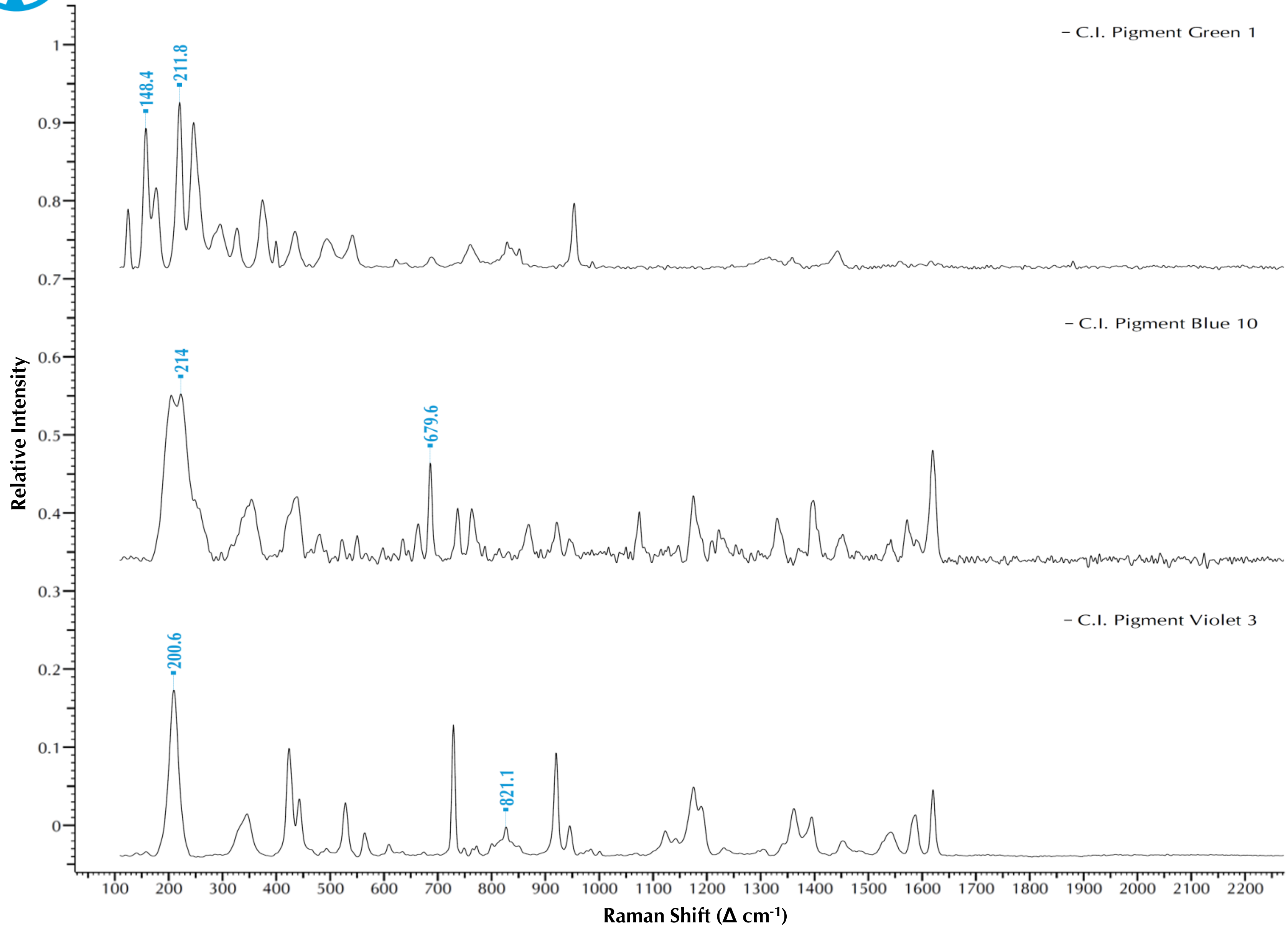


Triarylcarbonium – Group 1

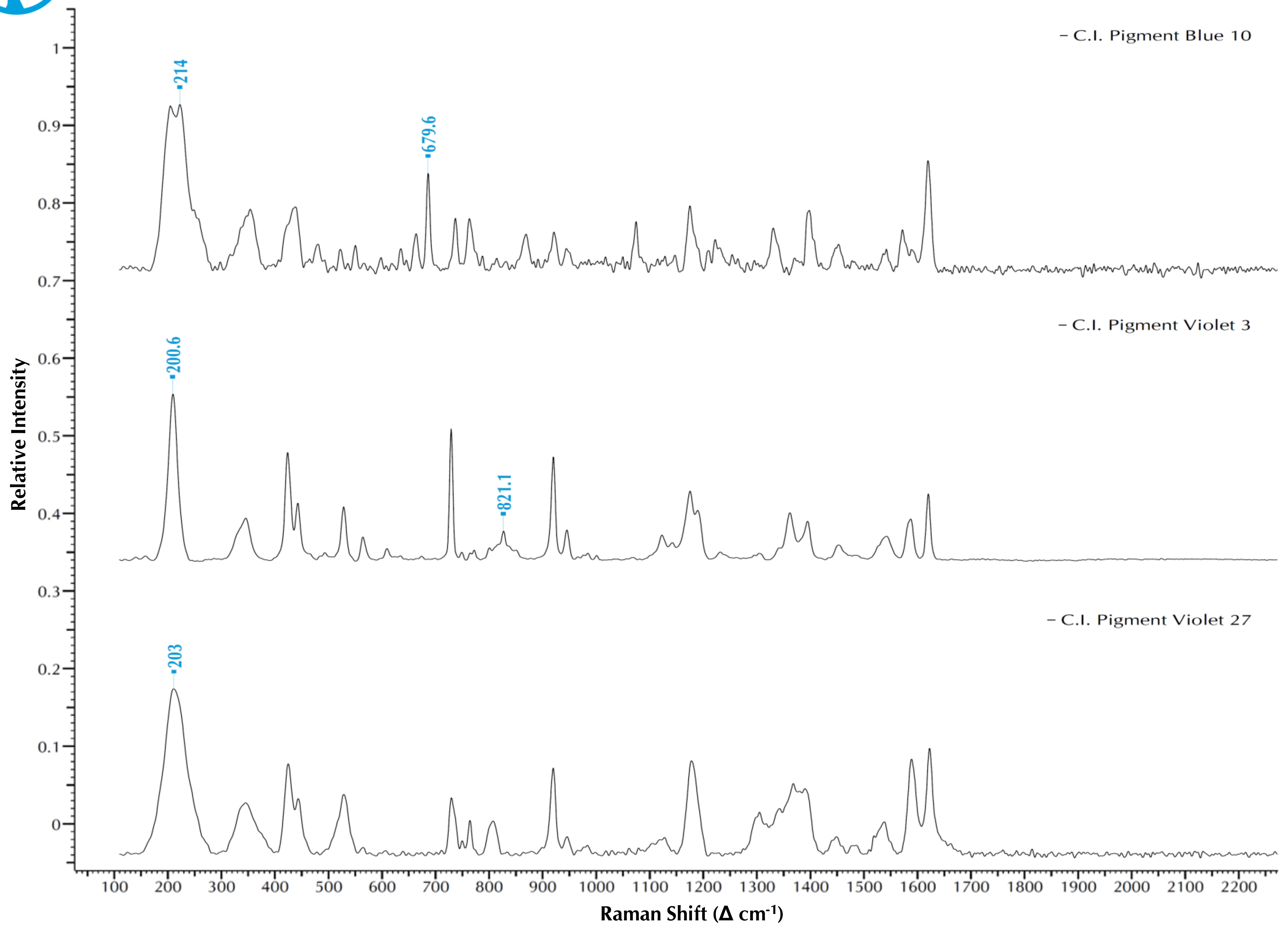




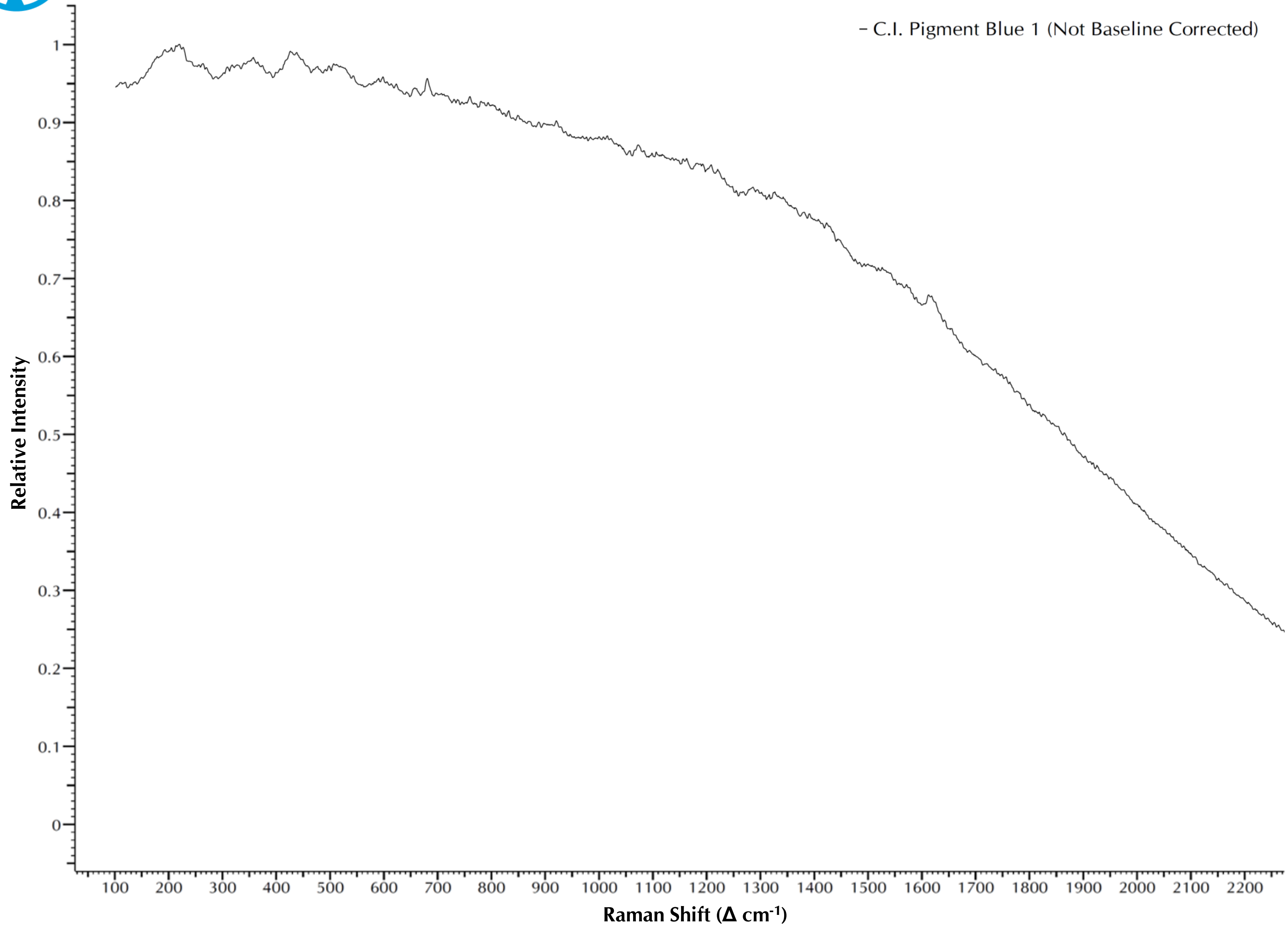
Triarylcarbonium – Group 1



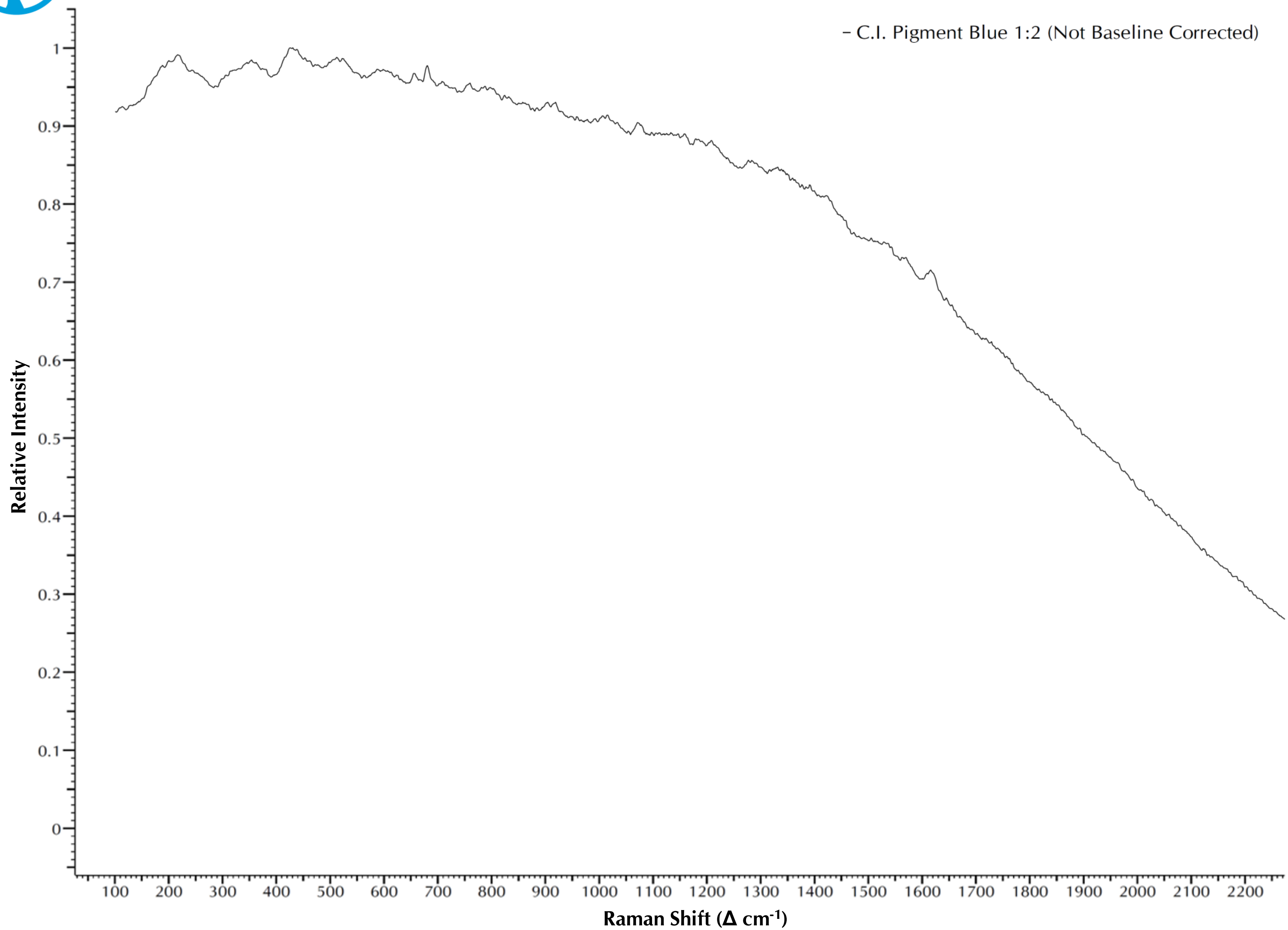
Triarylcarbonium – Group 1



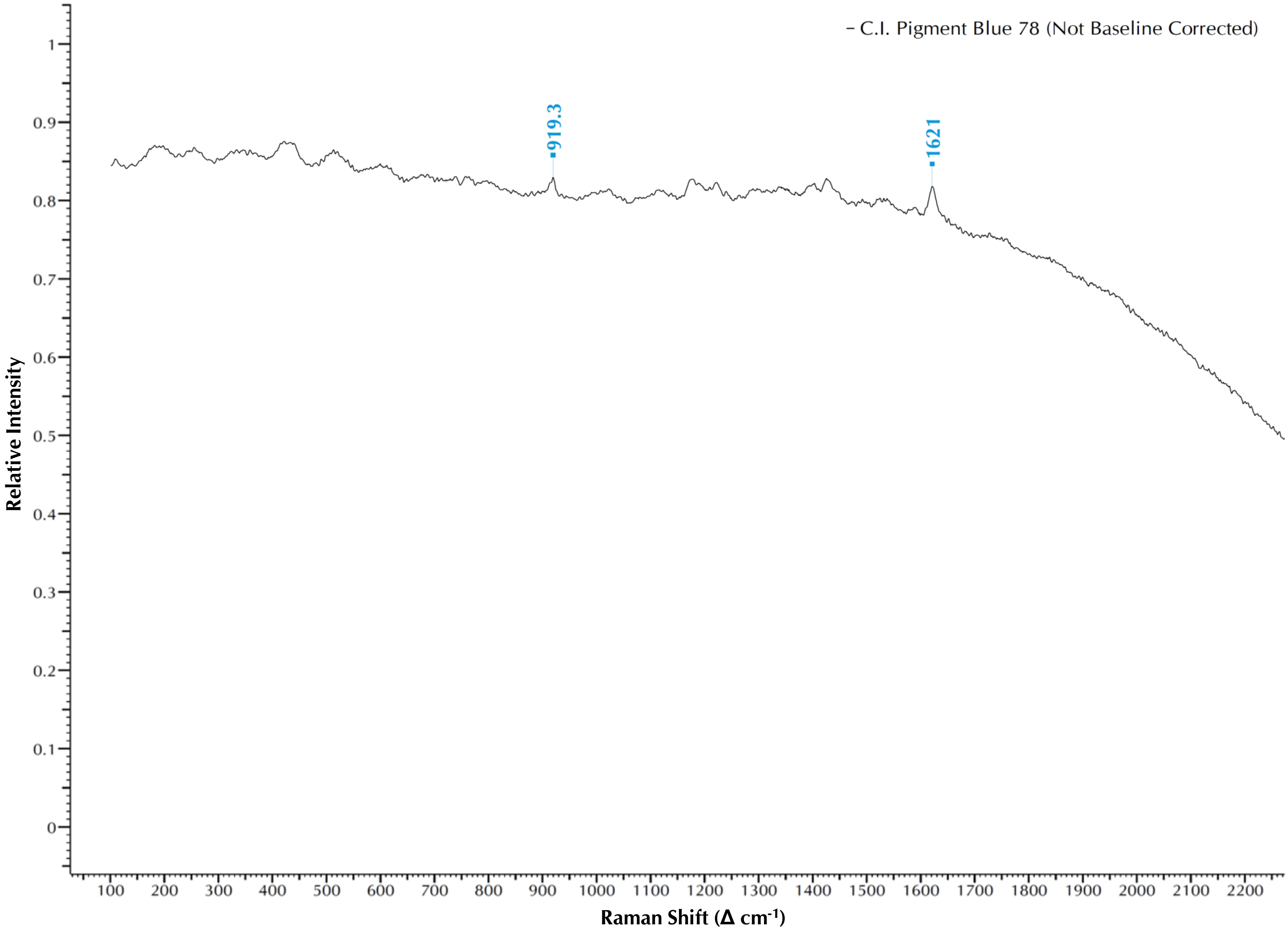
Triarylcarbonium – Group 1



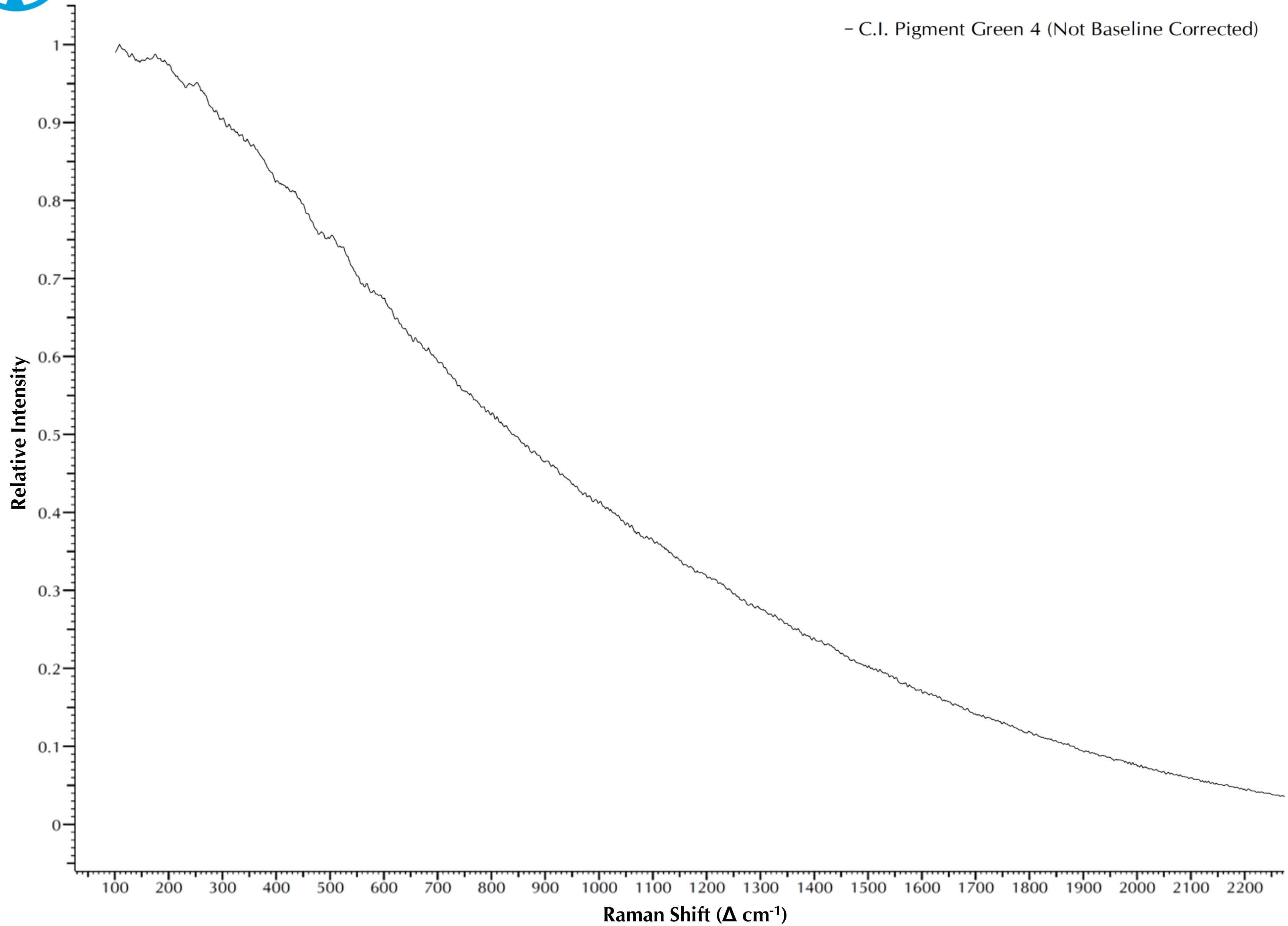
Triarylcarbonium – Group 1



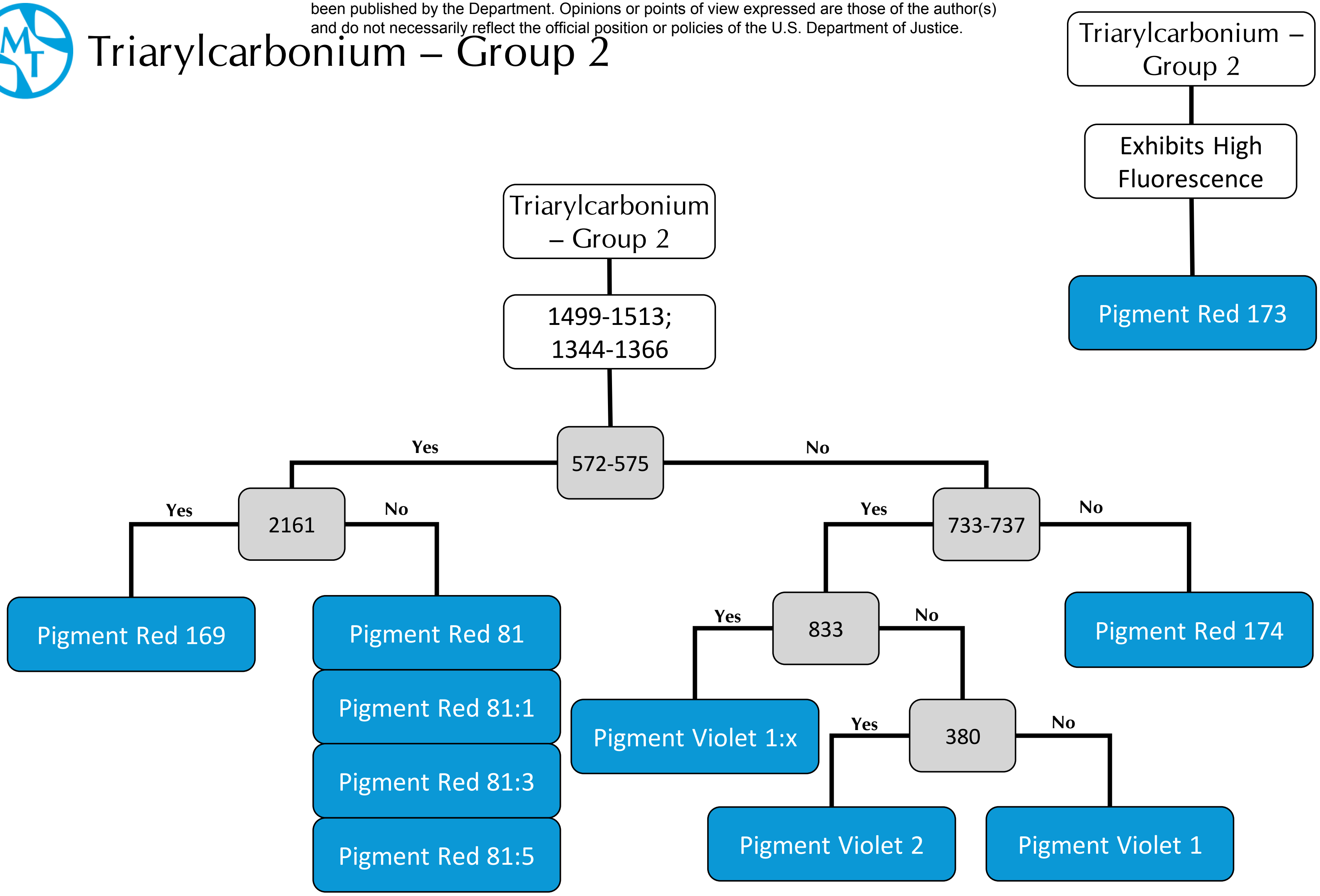
Triarylcarbonium – Group 1



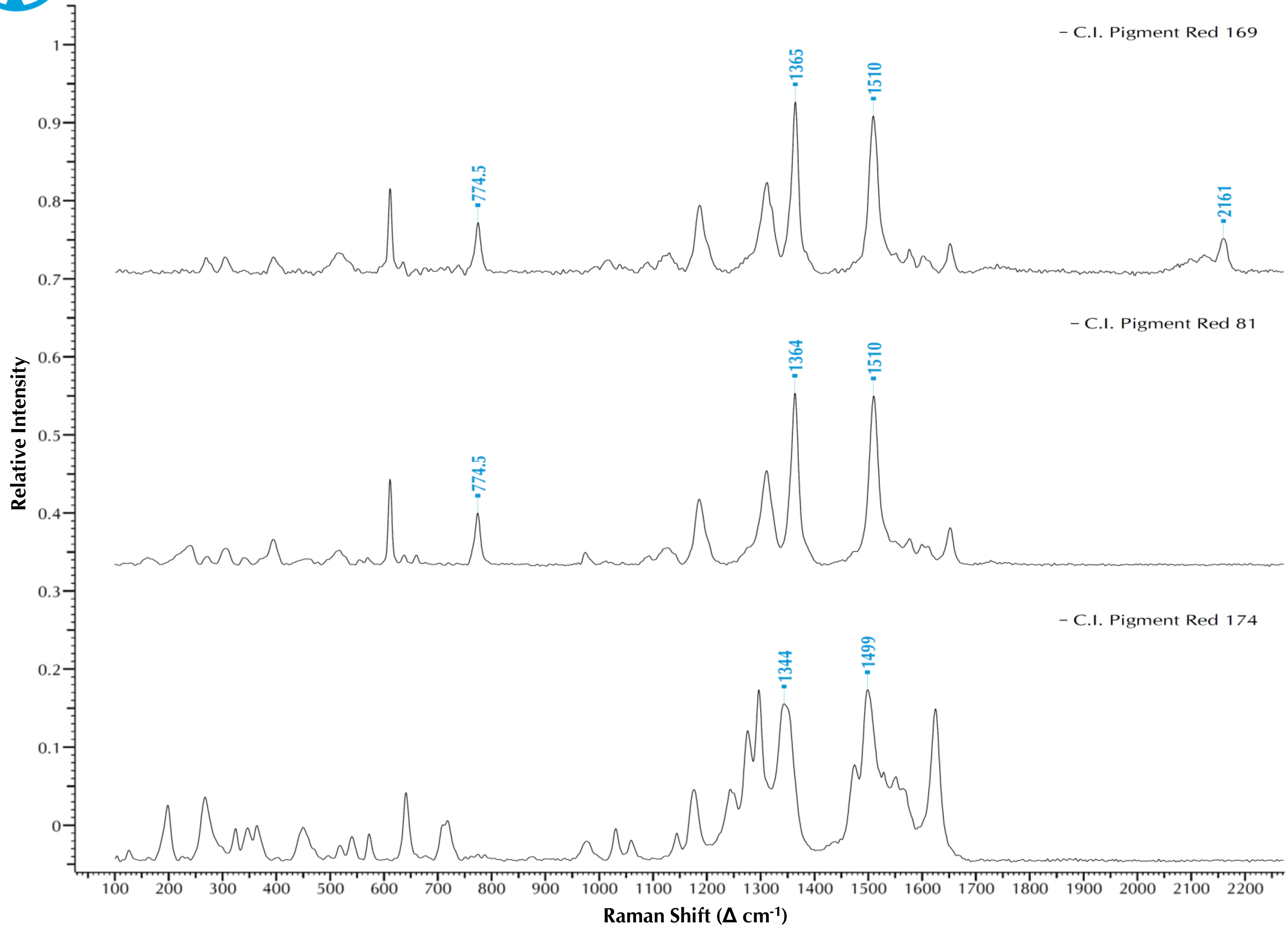
Triarylcarbonium – Group 1



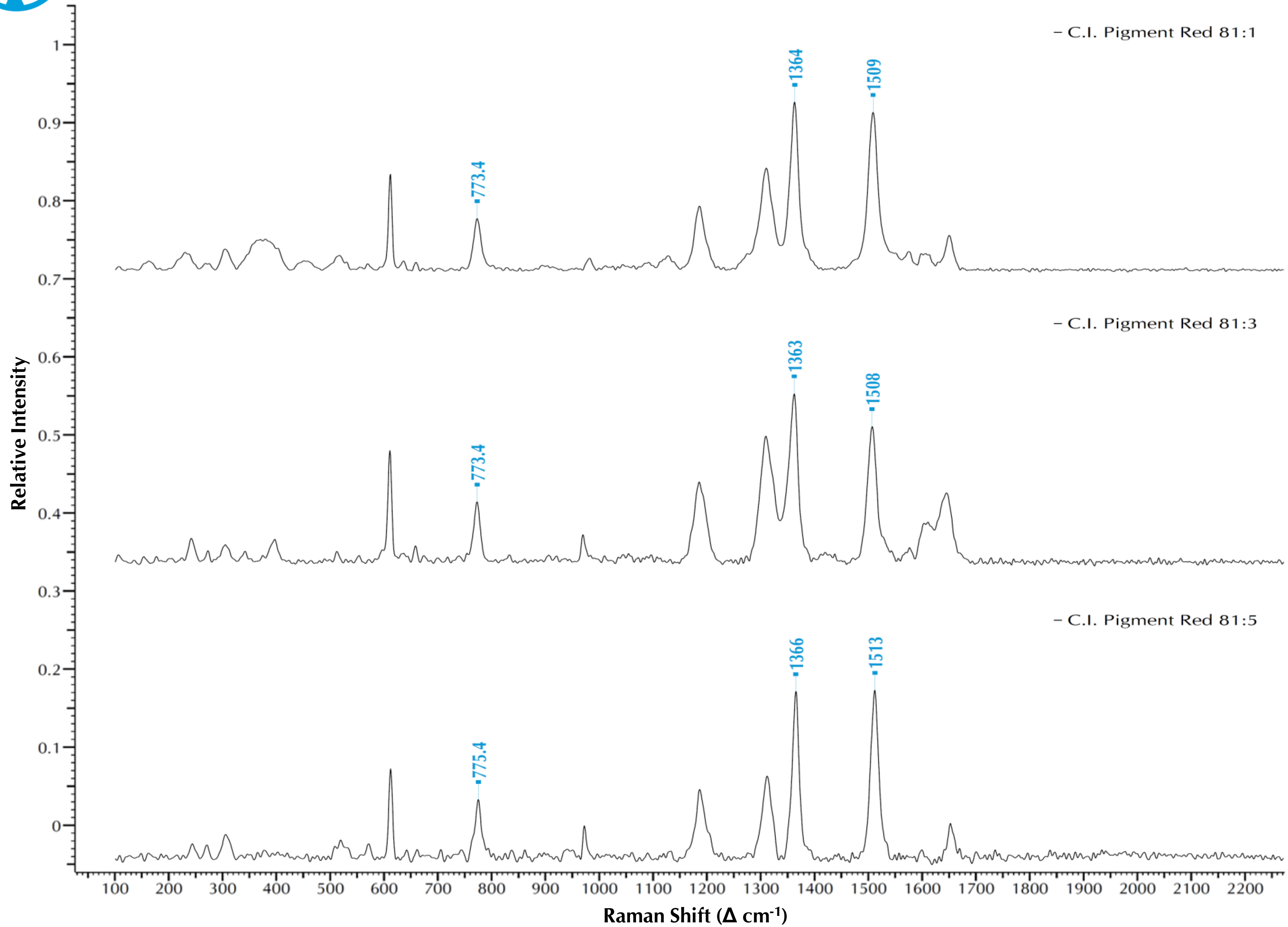
Triarylcarbonium – Group 2



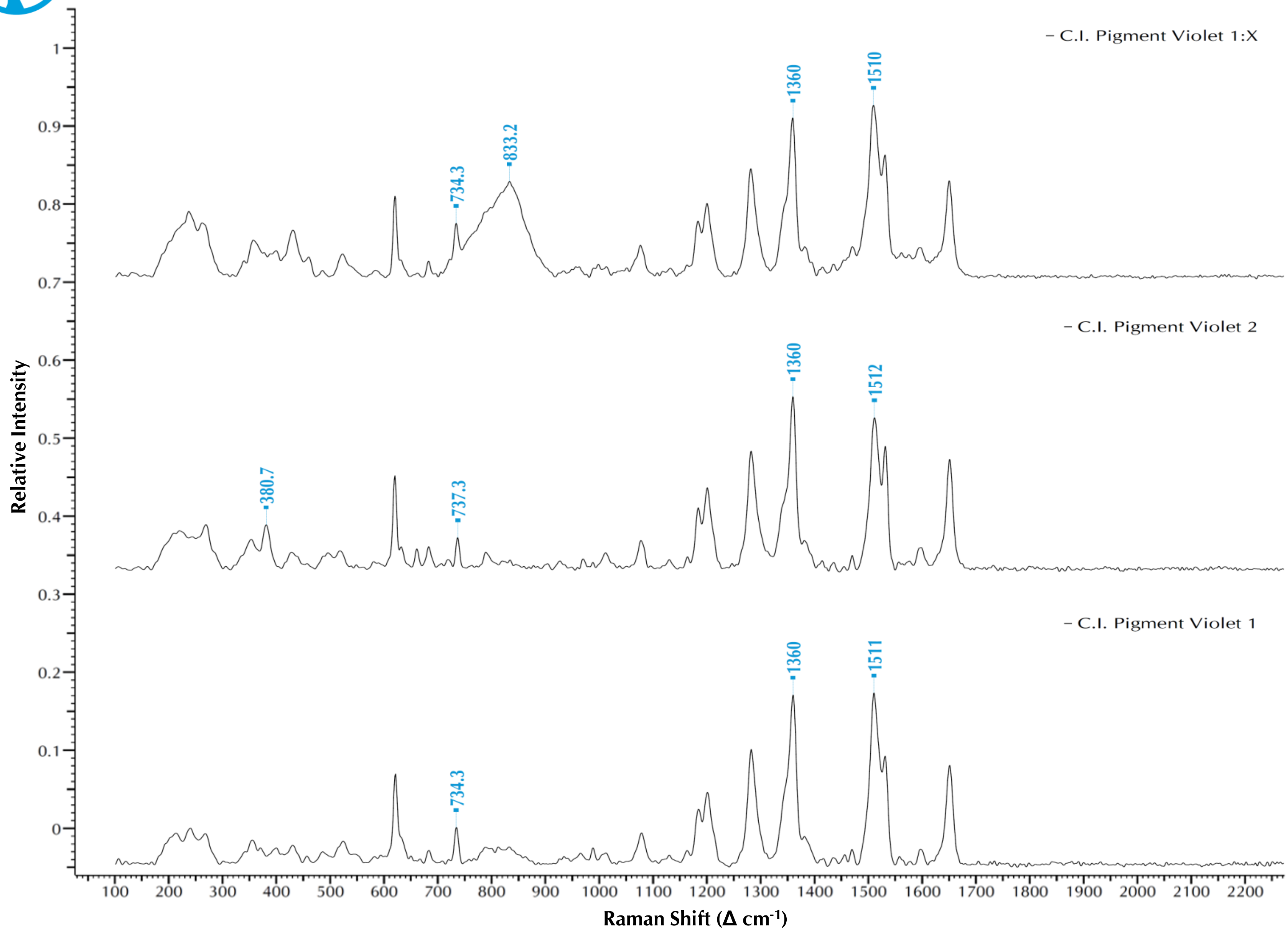
Triarylcarbonium – Group 2



Triarylcarbonium – Group 2

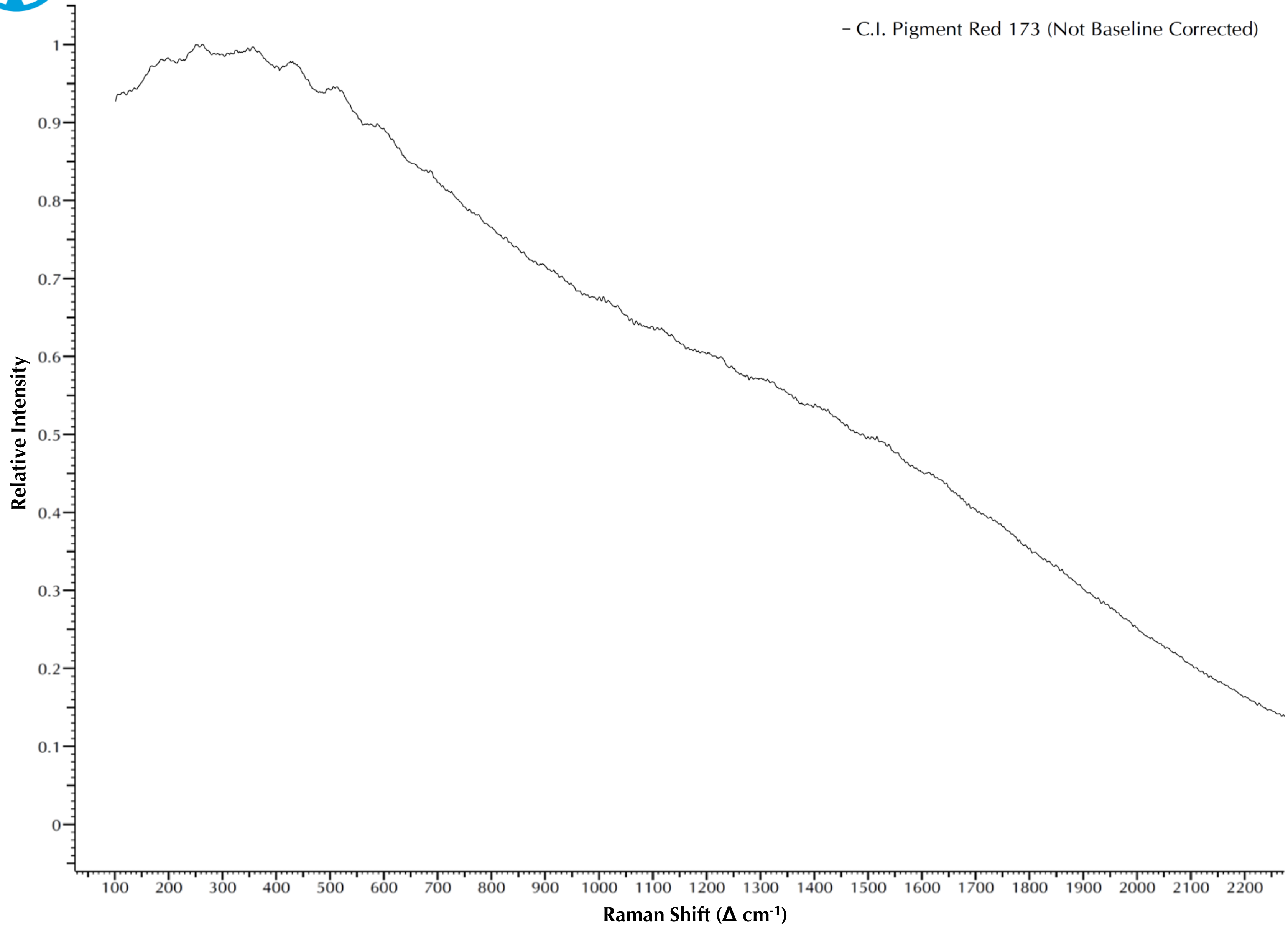


Triarylcarbonium – Group 2



Microtrace LLC

Triarylcarbonium – Group 1



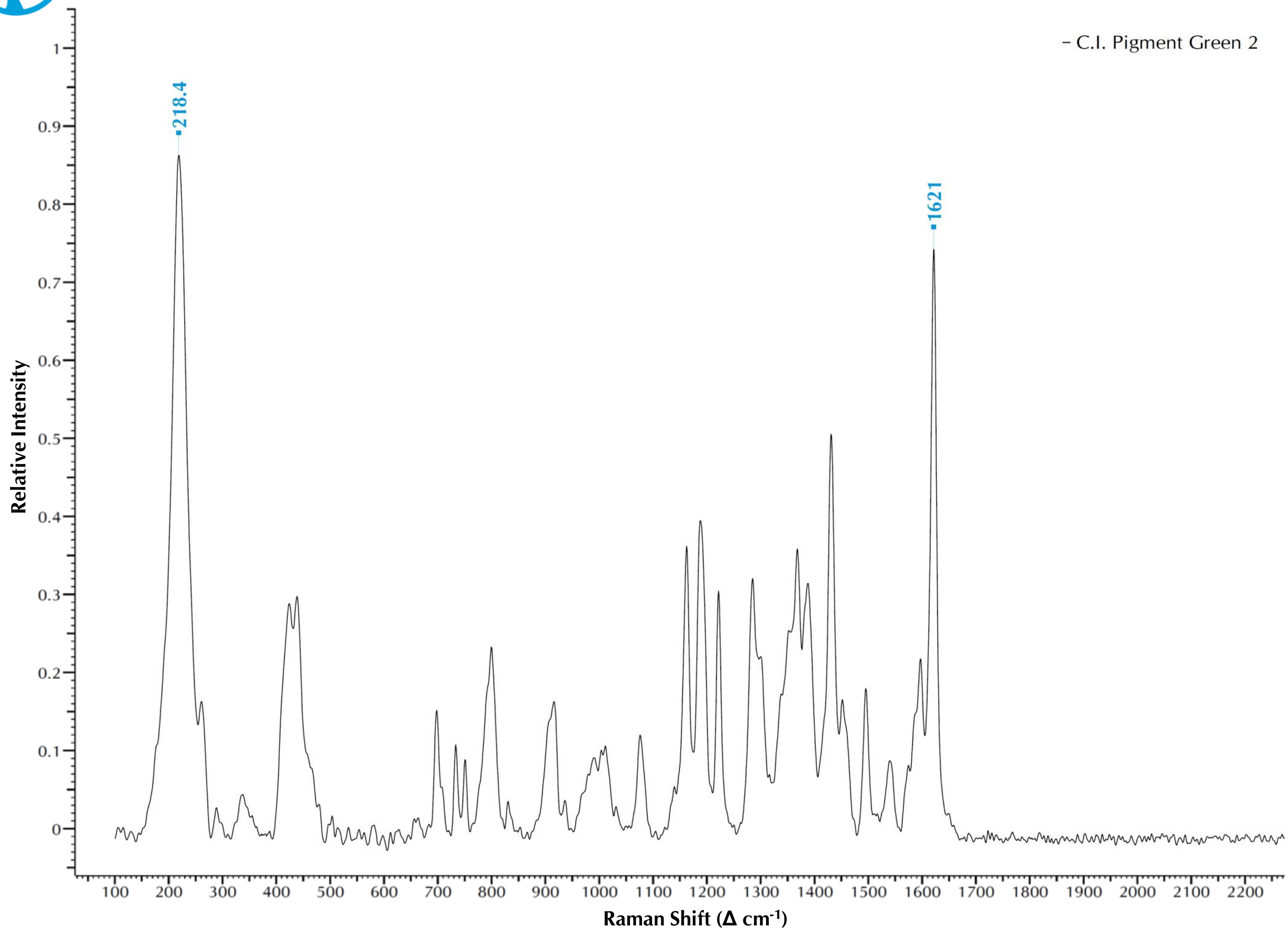
Triarylcarbonium – Group 3

Triarylcarbonium – Group 3

218;
1621

Pigment Green 2

Triarylcarbonium – Group 3



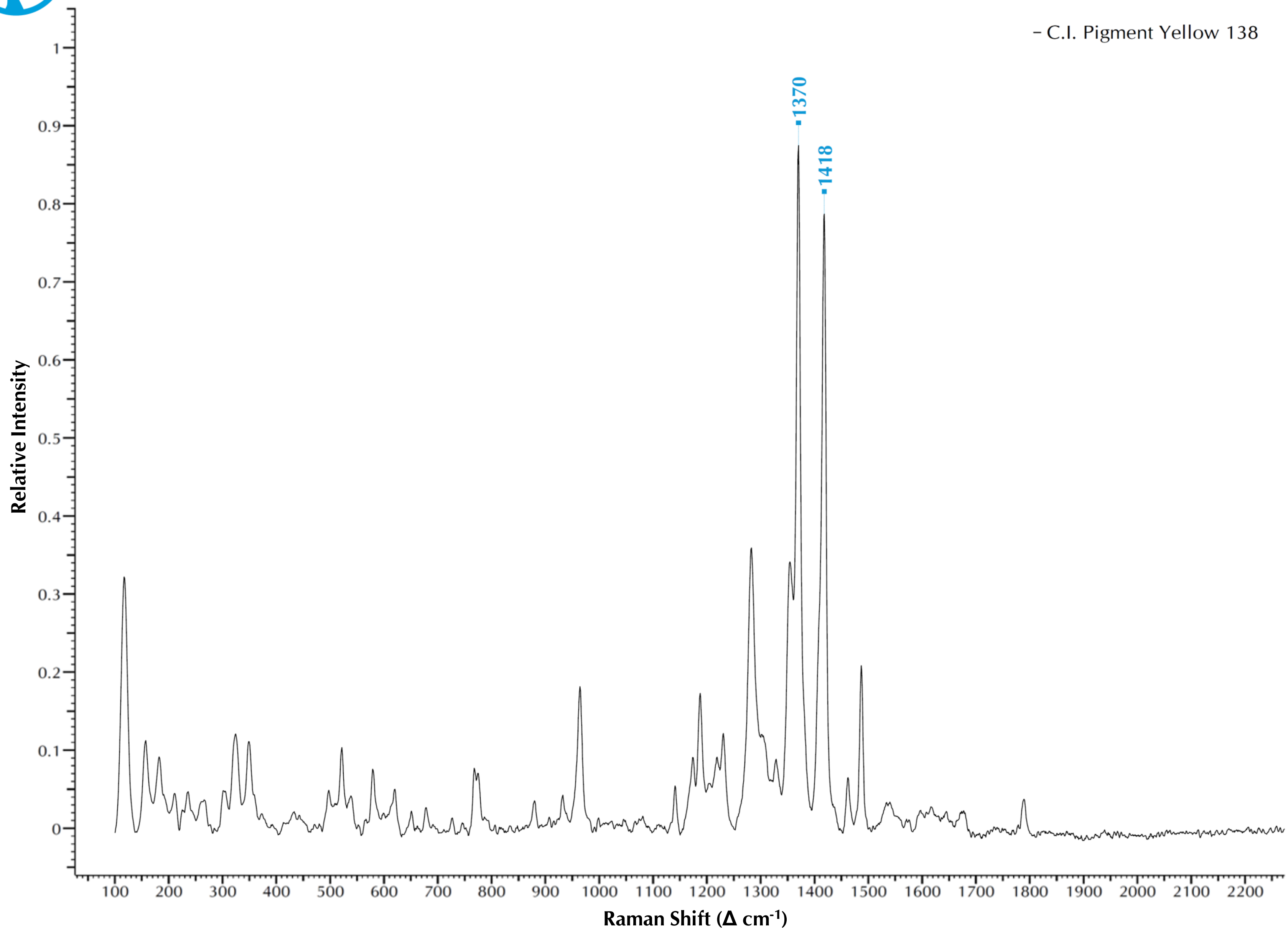
Quinophthalone

Quinophthalone

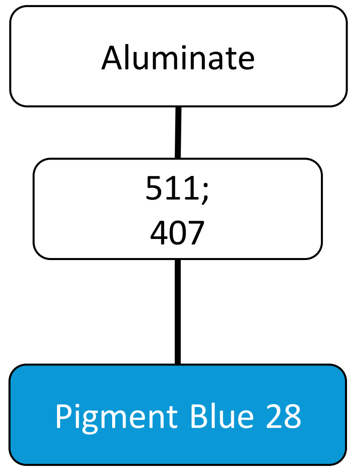
1370;
1418

Pigment Yellow 138

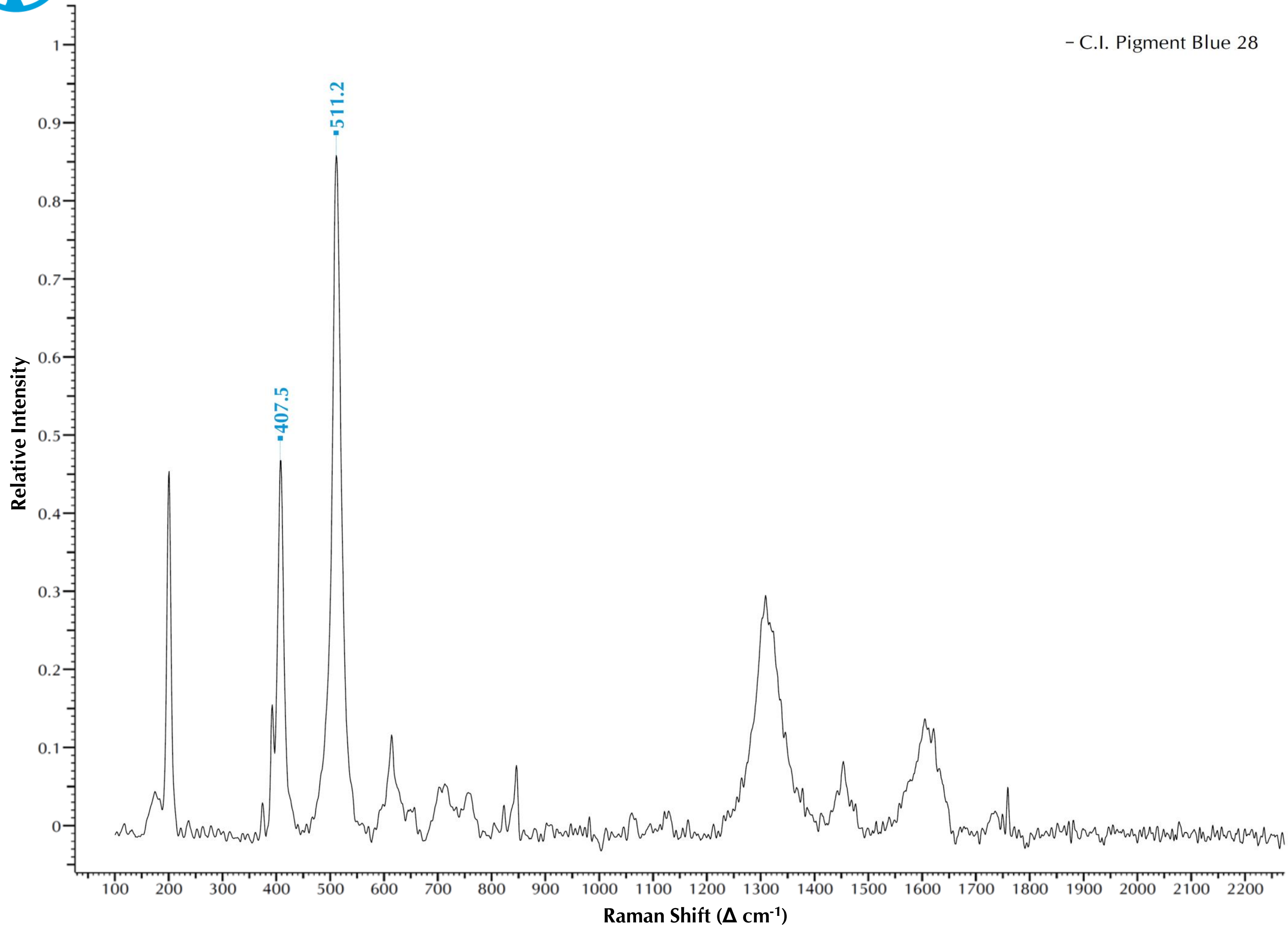
Quinophthalone



Aluminate

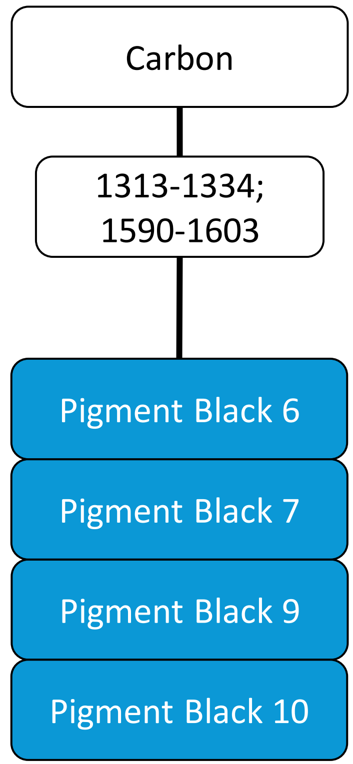


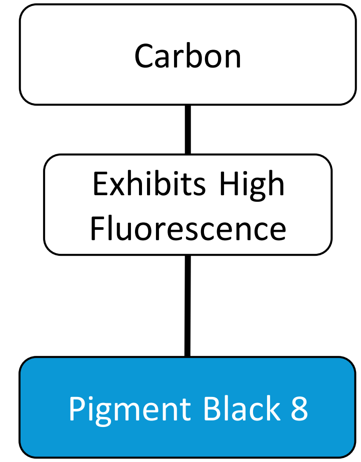
Aluminate



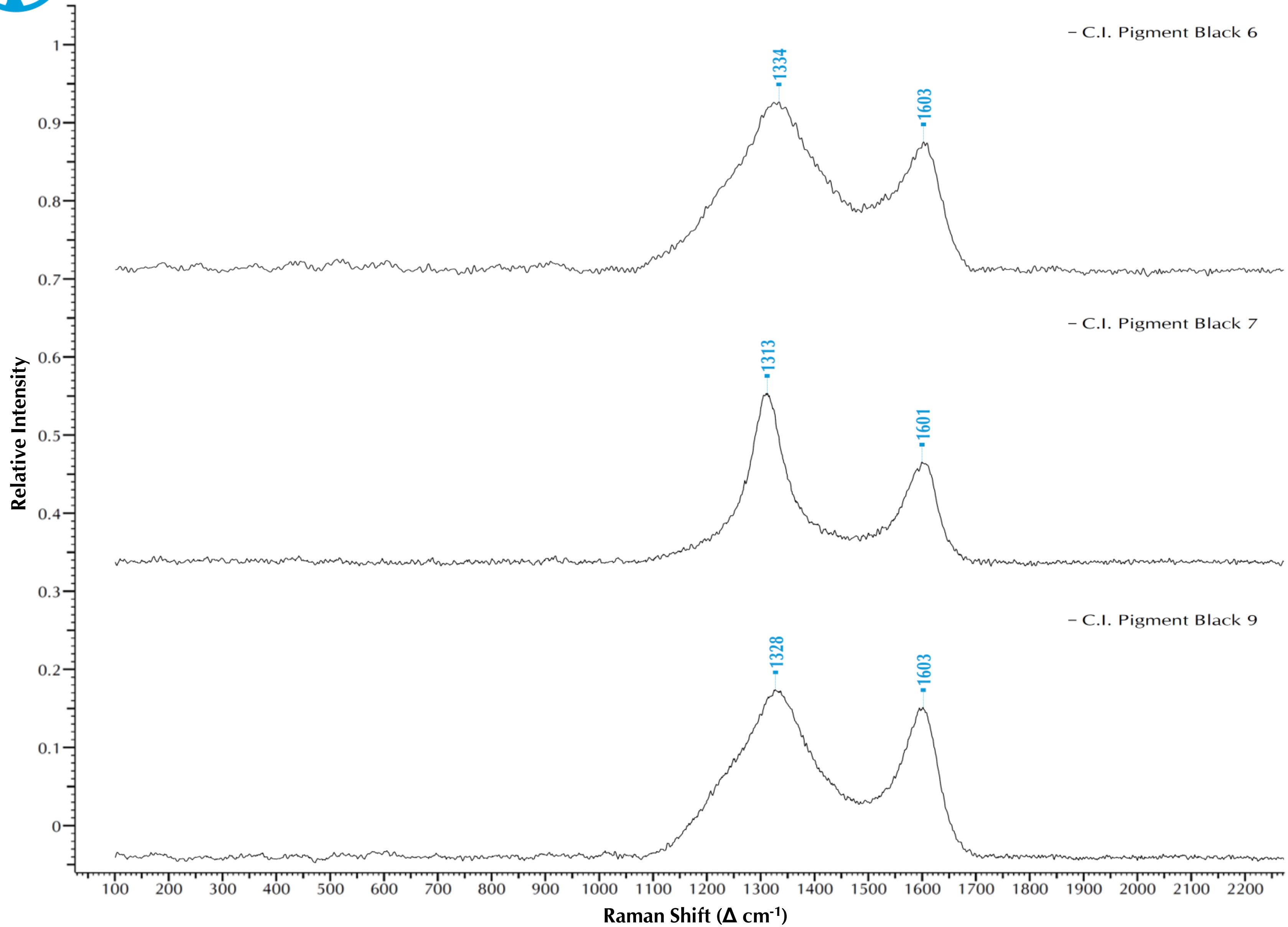
– C.I. Pigment Blue 28
511.2
407.5
Relative Intensity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Carbon


Carbon
1313-1334;
1590-1603
Pigment Black 6
Pigment Black 7
Pigment Black 9
Pigment Black 10

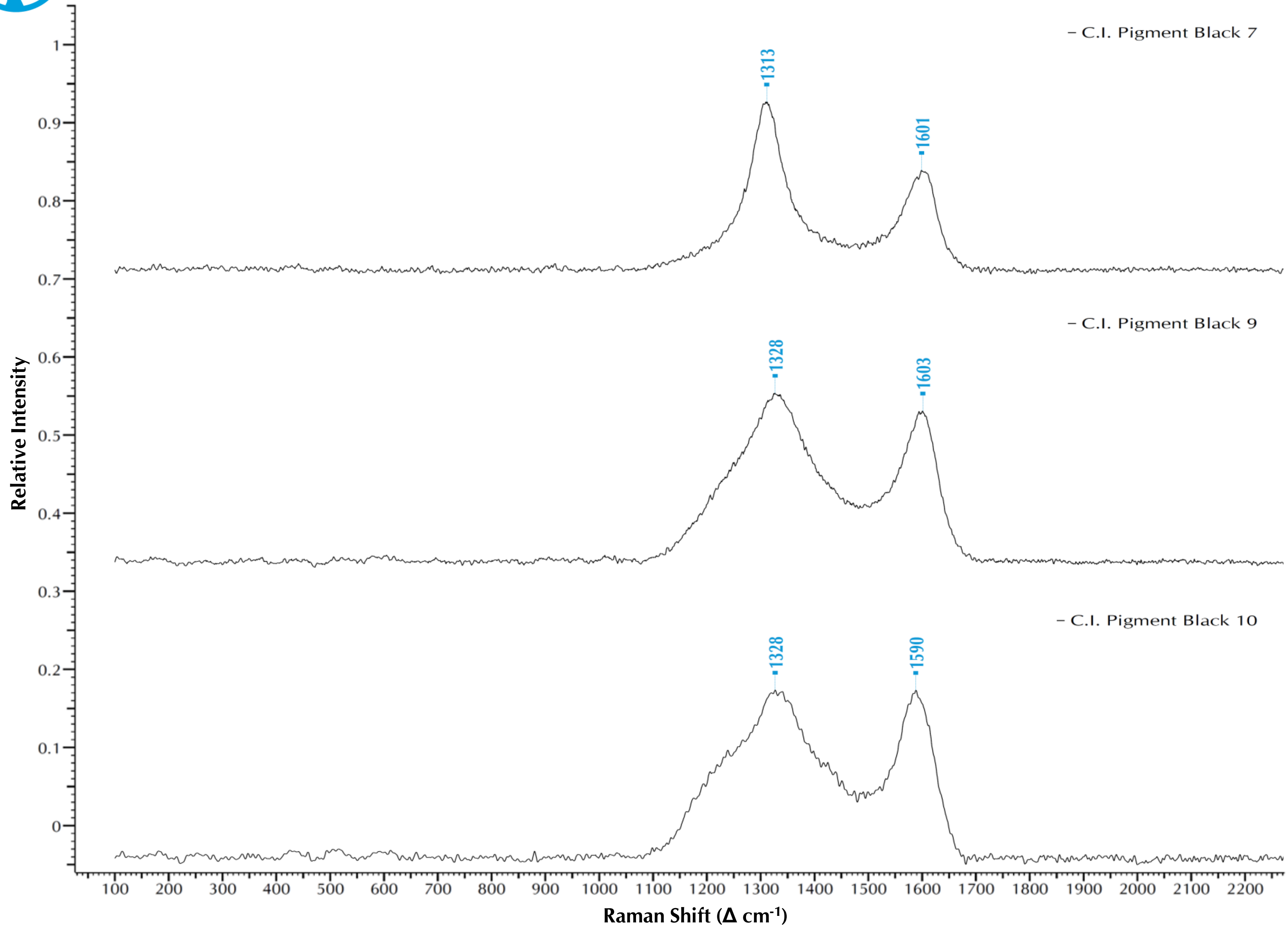

Carbon
Exhibits High Fluorescence
Pigment Black 8

Carbon

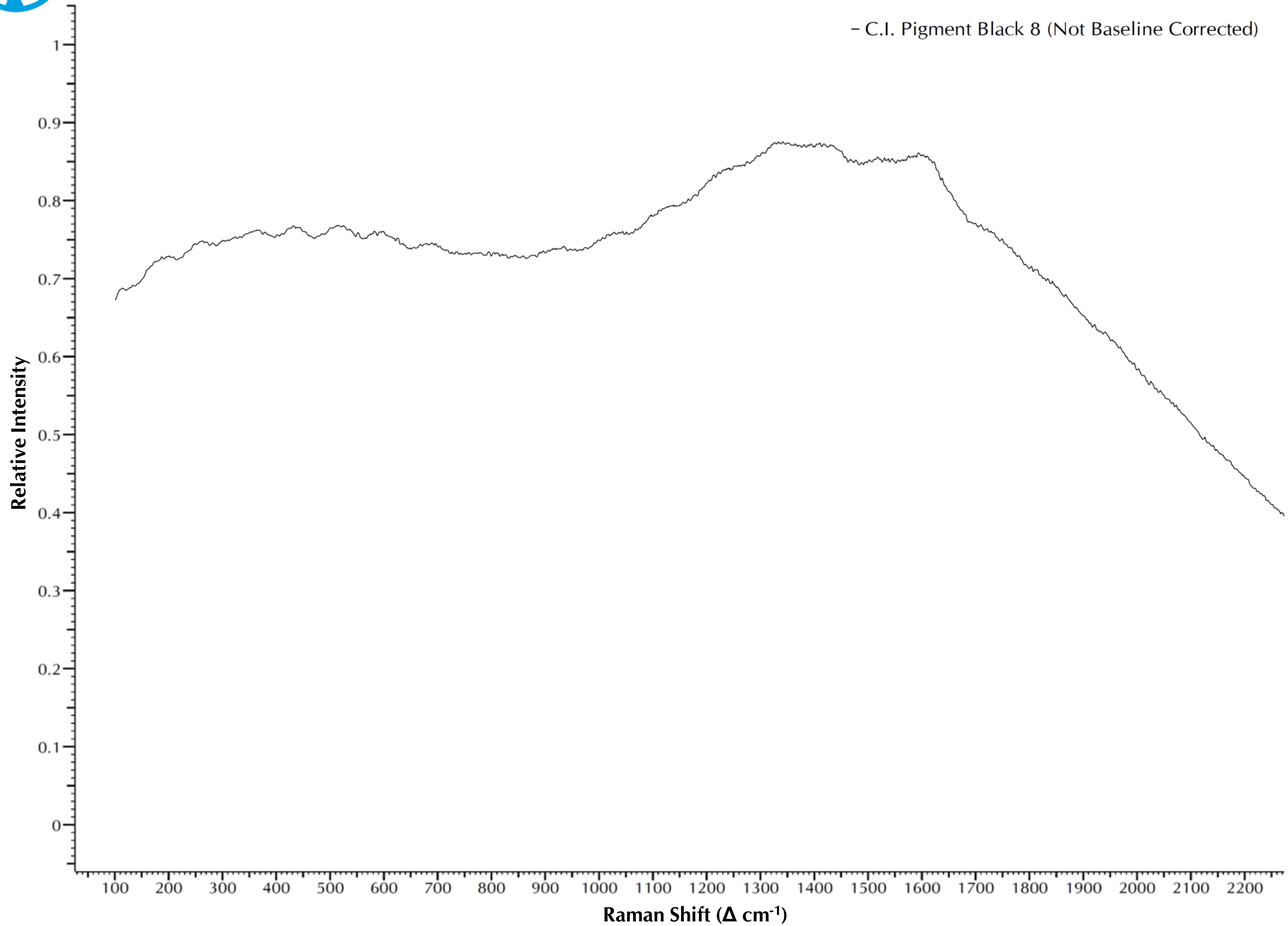


– C.I. Pigment Black 6
1334
1603
– C.I. Pigment Black 7
1313
1601
– C.I. Pigment Black 9
1328
1603
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200
Raman Shift (Δ cm-1)

Carbon

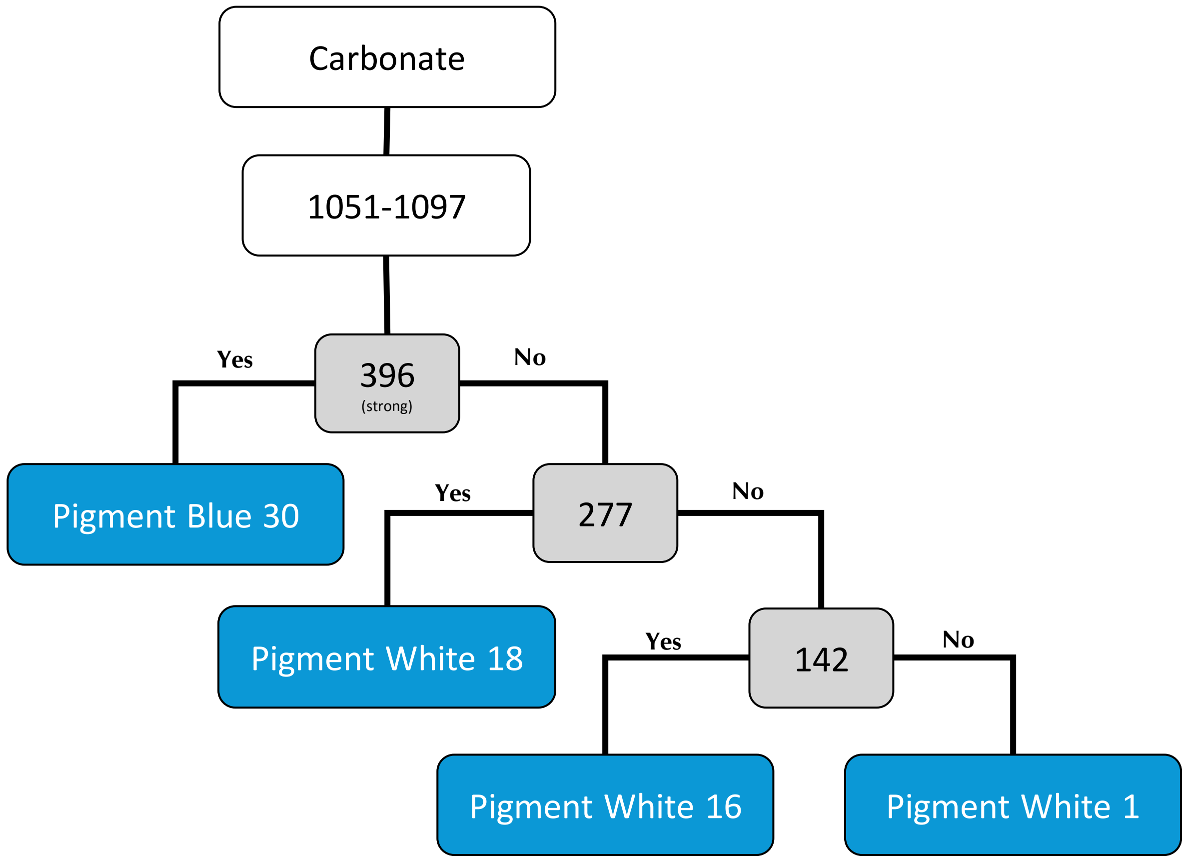

– C.I. Pigment Black 7
– C.I. Pigment Black 9
– C.I. Pigment Black 10
1313
1601
1328
1603
1328
1590
Relative Intensity
Raman Shift (Δ cm-1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Carbon

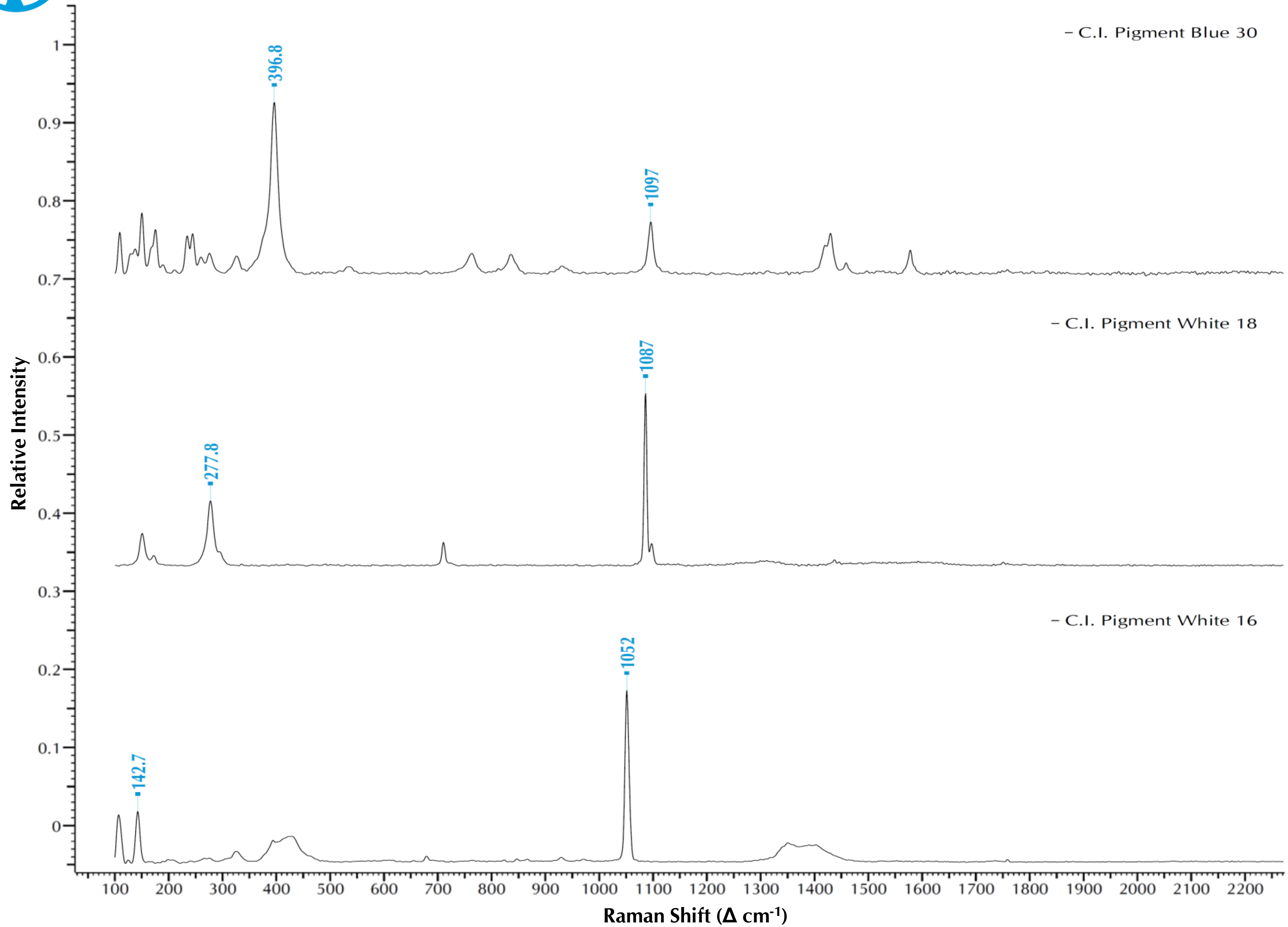


– C.I. Pigment Black 8 (Not Baseline Corrected)
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Carbonate

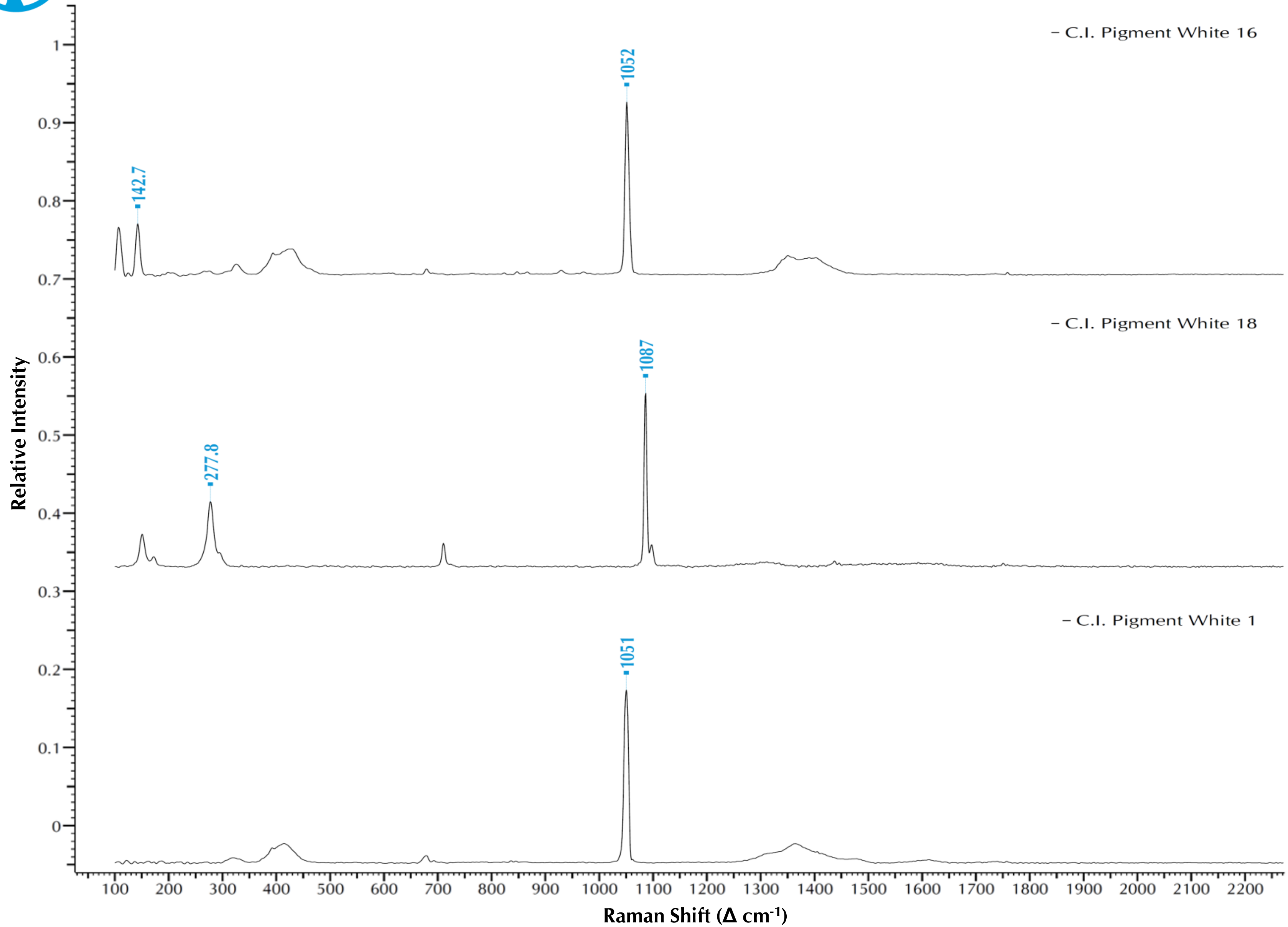

Carbonate
1051-1097
396
(strong)
Yes
No
Pigment Blue 30
277
Yes
No
Pigment White 18
142
Yes
No
Pigment White 16
Pigment White 1

Carbonate



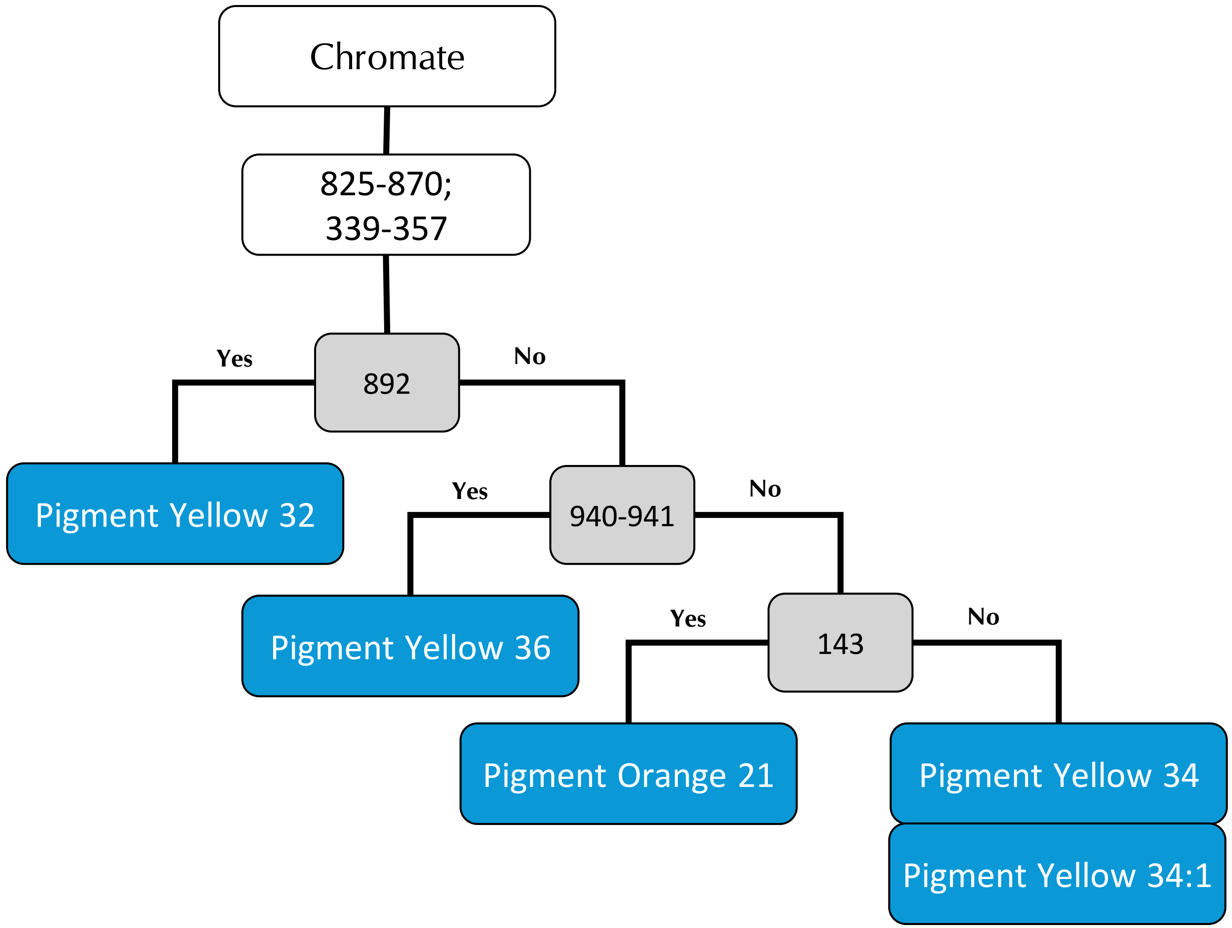
– C.I. Pigment Blue 30
– C.I. Pigment White 18
– C.I. Pigment White 16
396.8
1097
277.8
1087
142.7
1052
Relative Intensity
Raman Shift (Δ cm⁻¹)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Carbonate

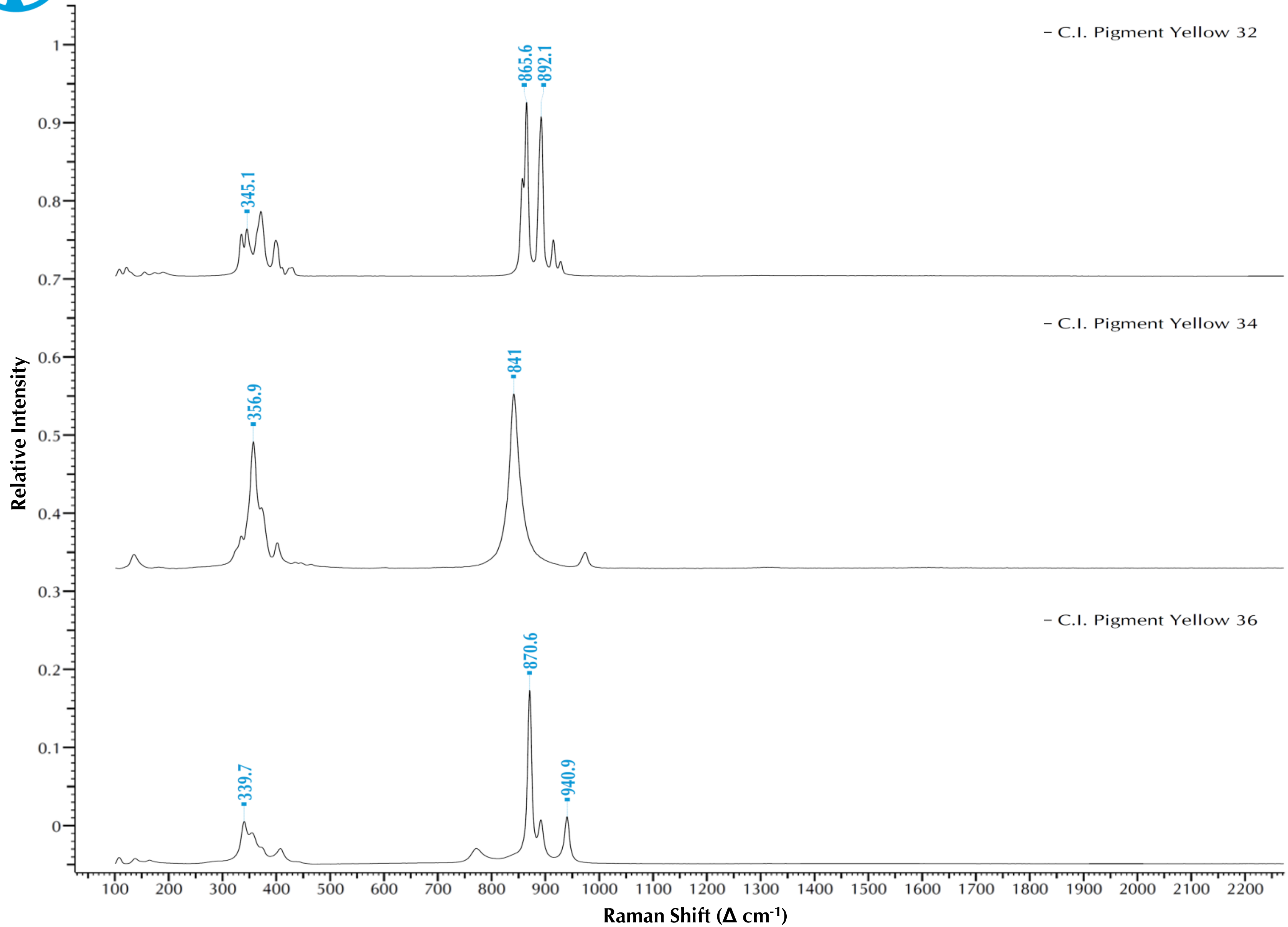


– C.I. Pigment White 16
– C.I. Pigment White 18
– C.I. Pigment White 1
1052
142.7
1087
277.8
1051
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Chromate

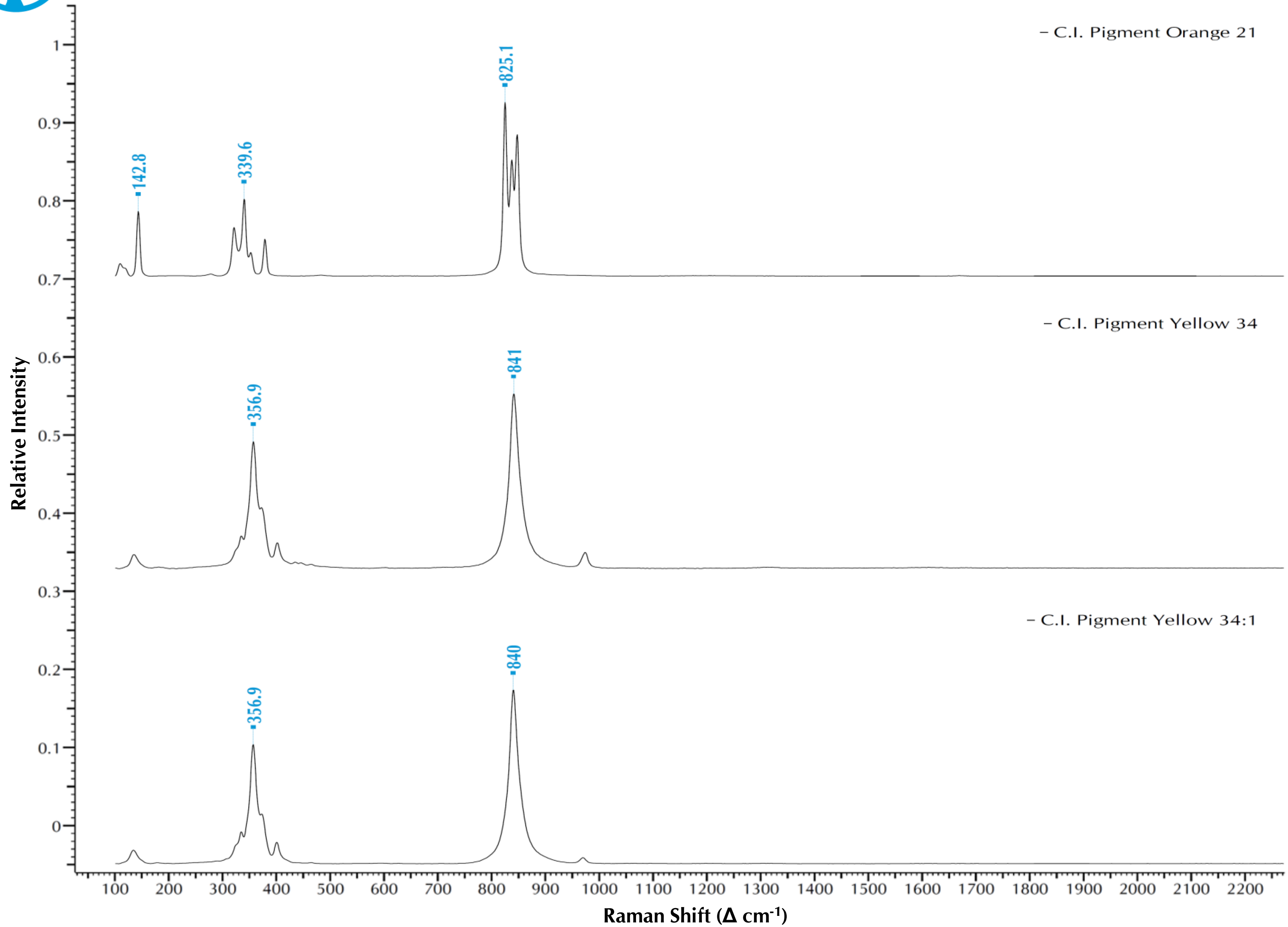

Chromate
825-870;
339-357
892
Yes
No
Pigment Yellow 32
940-941
Yes
No
Pigment Yellow 36
143
Yes
No
Pigment Orange 21
Pigment Yellow 34
Pigment Yellow 34:1

Chromate



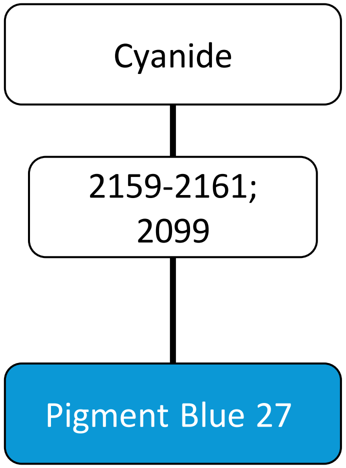
– C.I. Pigment Yellow 32
– C.I. Pigment Yellow 34
– C.I. Pigment Yellow 36
345.1
865.6
892.1
356.9
841
339.7
870.6
940.9
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Chromate

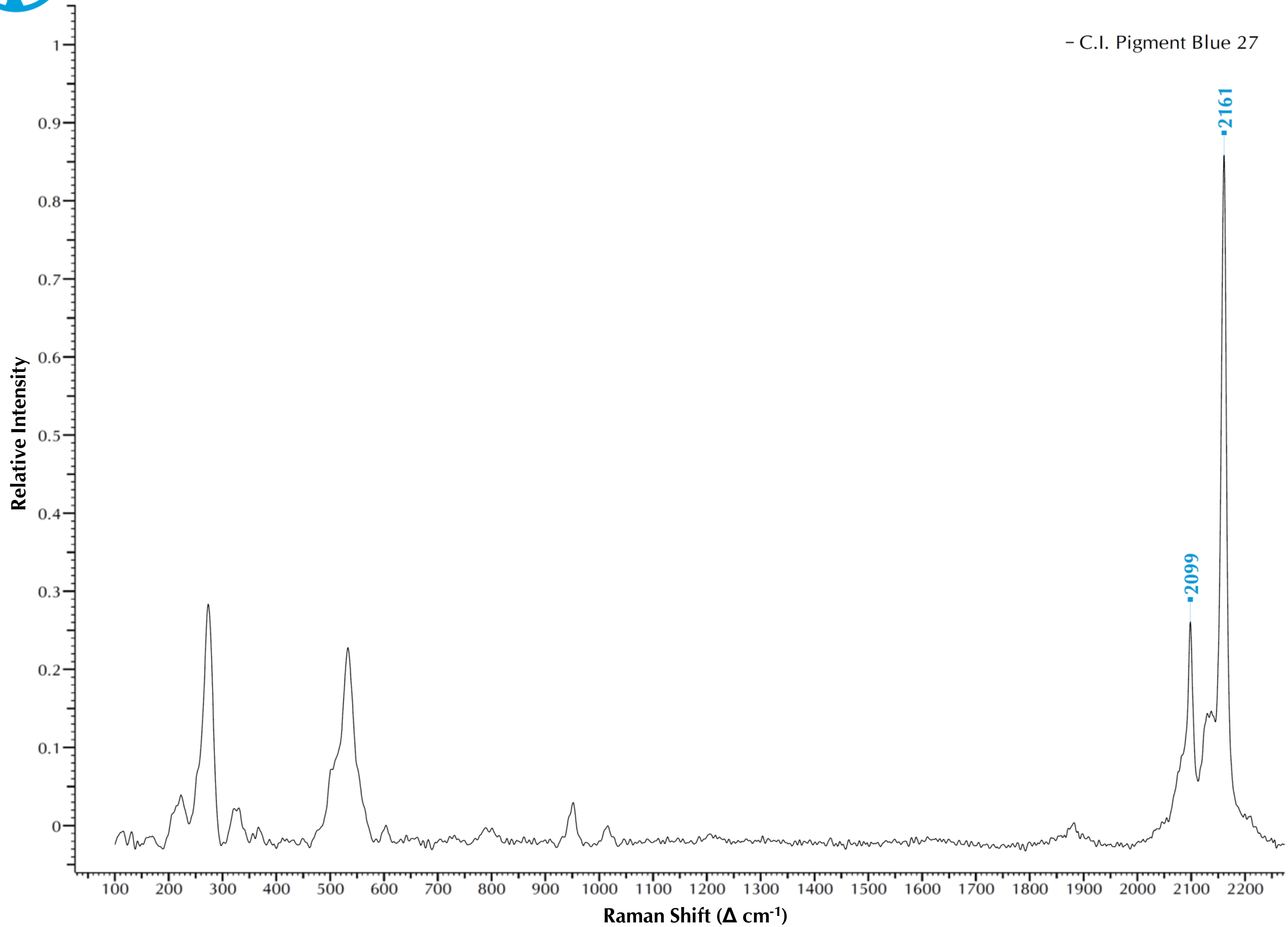


– C.I. Pigment Orange 21
– C.I. Pigment Yellow 34
– C.I. Pigment Yellow 34:1
142.8
339.6
825.1
356.9
841
356.9
840
Relative Intensity
Raman Shift (Δ cm-1)

Cyanide

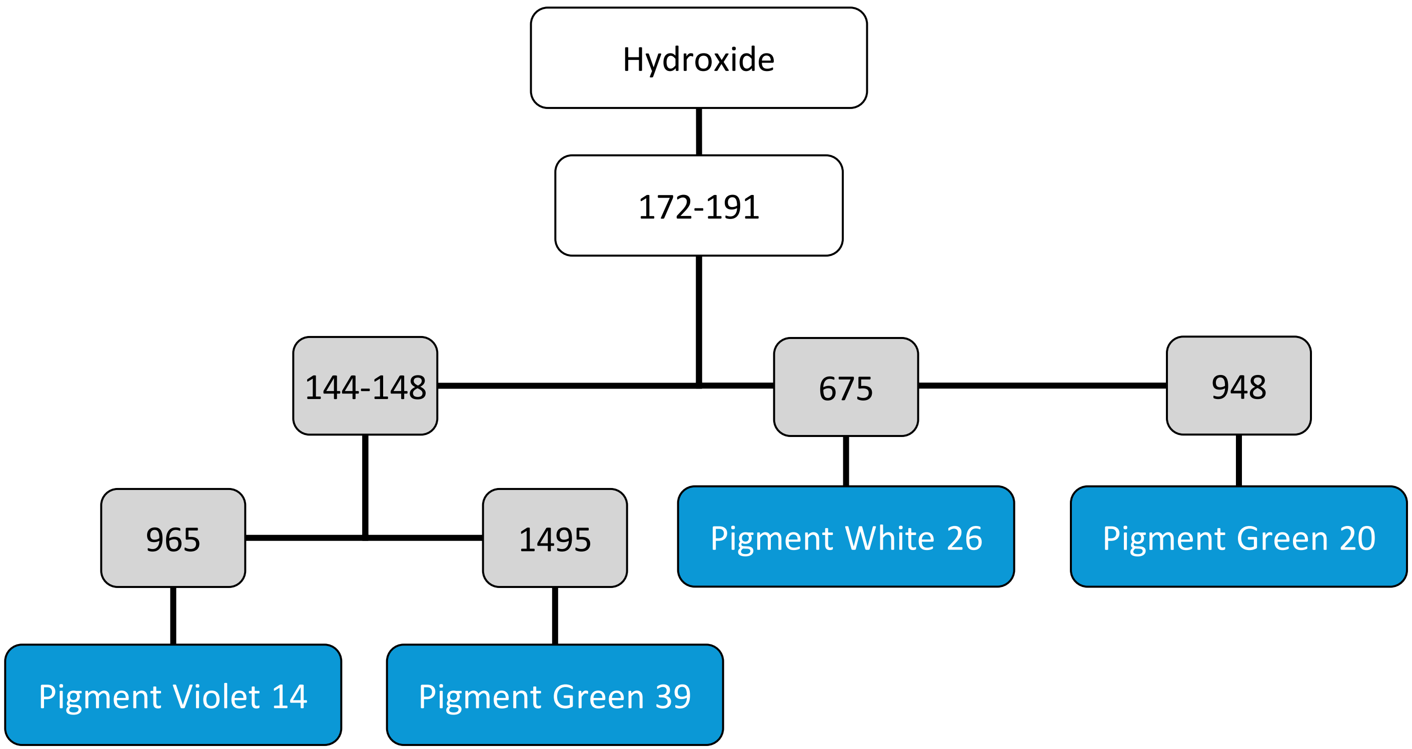


Cyanide

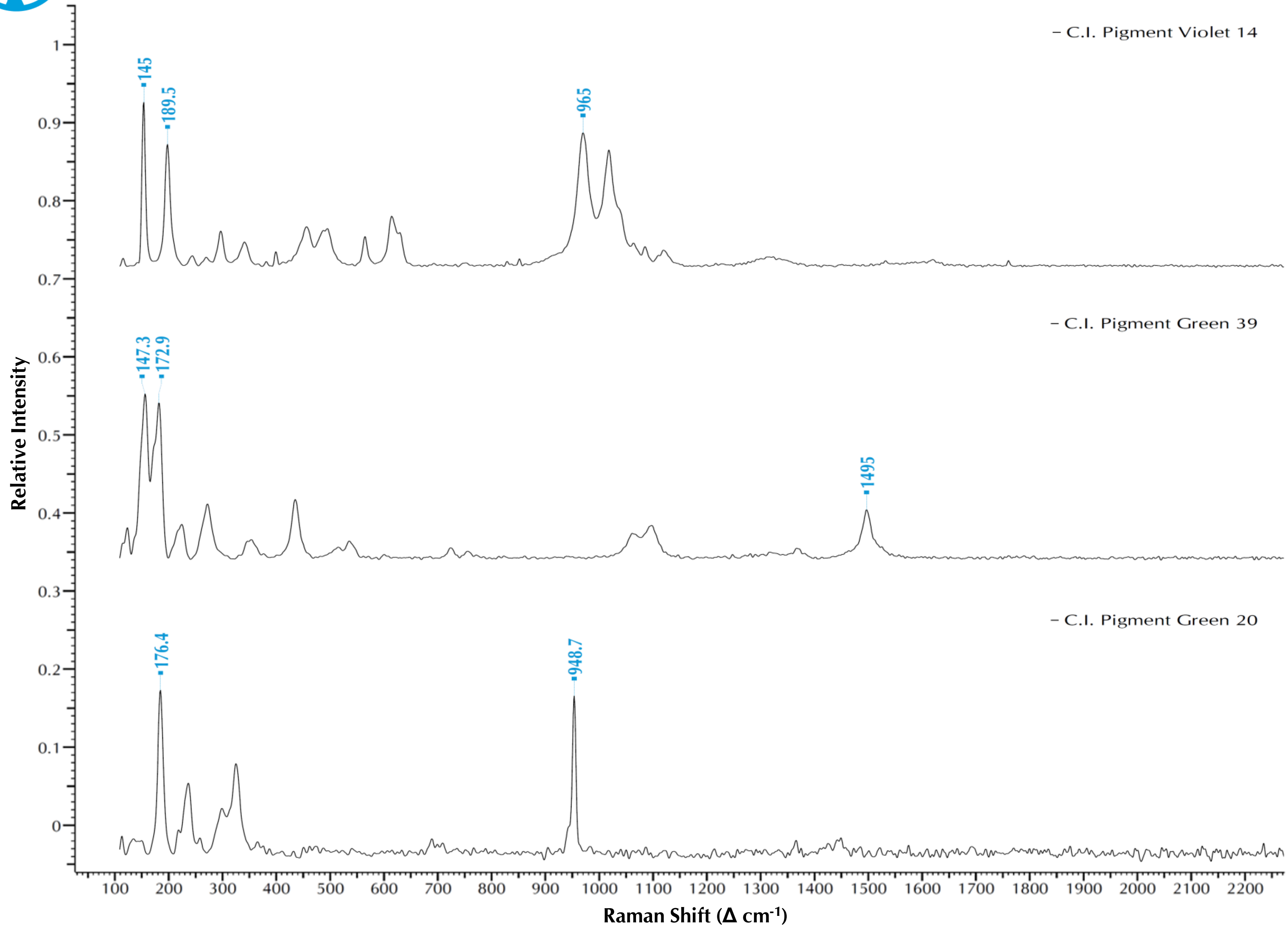


– C.I. Pigment Blue 27
2161
2099
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Hydroxide

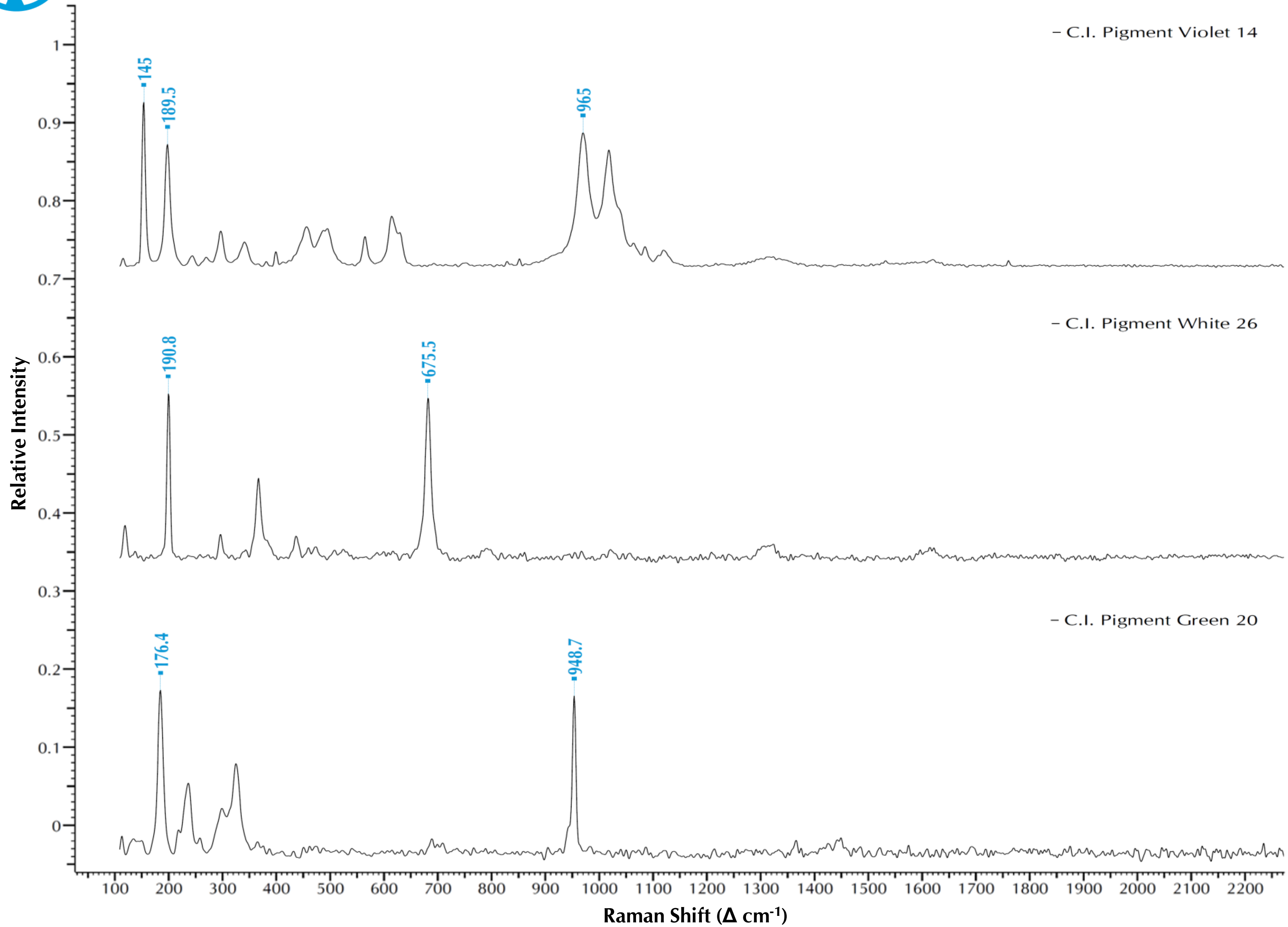

Hydroxide
172-191
144-148
675
948
965
1495
Pigment White 26
Pigment Green 20
Pigment Violet 14
Pigment Green 39

Hydroxide



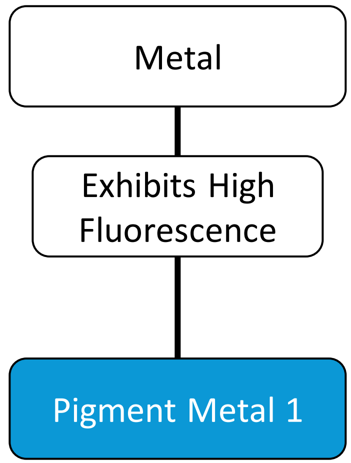
– C.I. Pigment Violet 14
145
189.5
965
– C.I. Pigment Green 39
147.3
172.9
1495
– C.I. Pigment Green 20
176.4
948.7
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Hydroxide

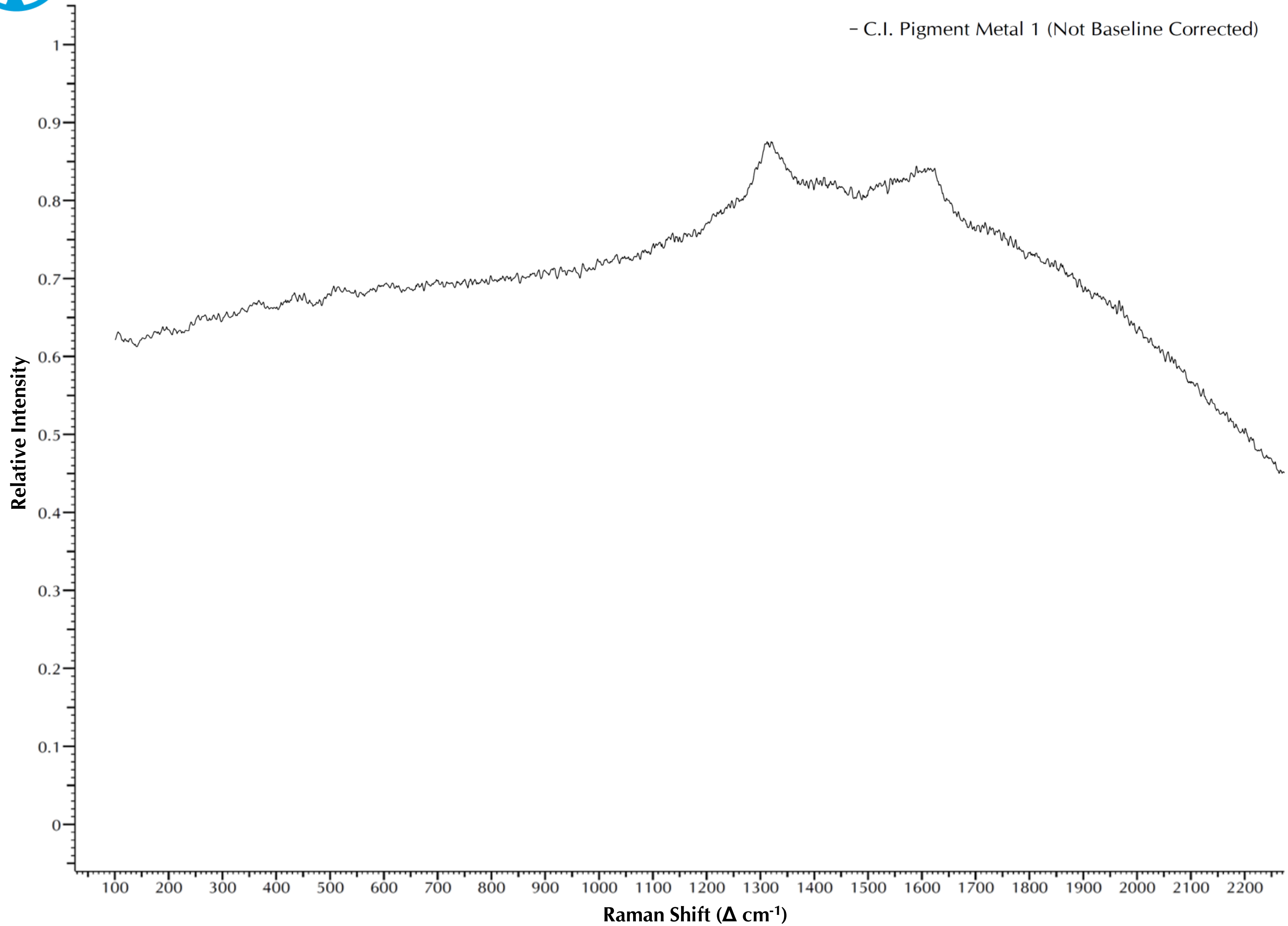


– C.I. Pigment Violet 14
145
189.5
965
– C.I. Pigment White 26
190.8
675.5
– C.I. Pigment Green 20
176.4
948.7
Relative Intensity
Raman Shift (Δ cm-1)

Metal

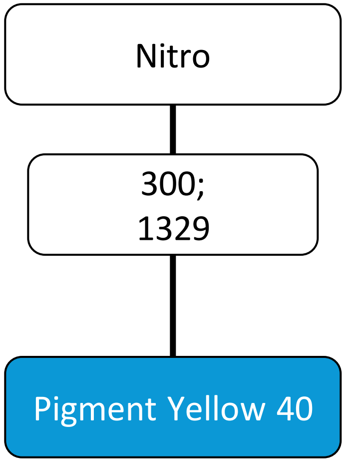


Metal

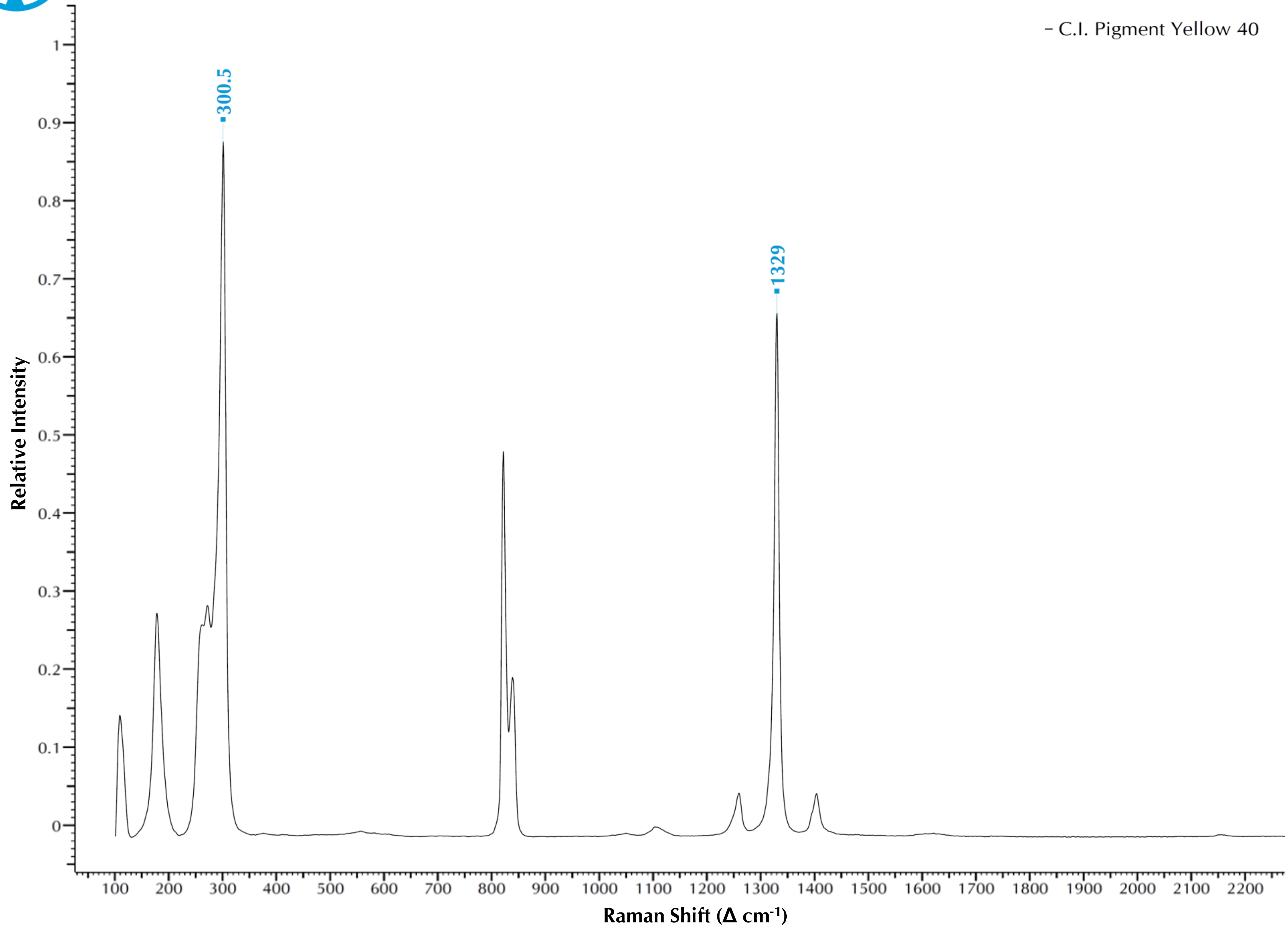


– C.I. Pigment Metal 1 (Not Baseline Corrected)
Relative Intensity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Raman Shift (Δ cm⁻¹)
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Nitro

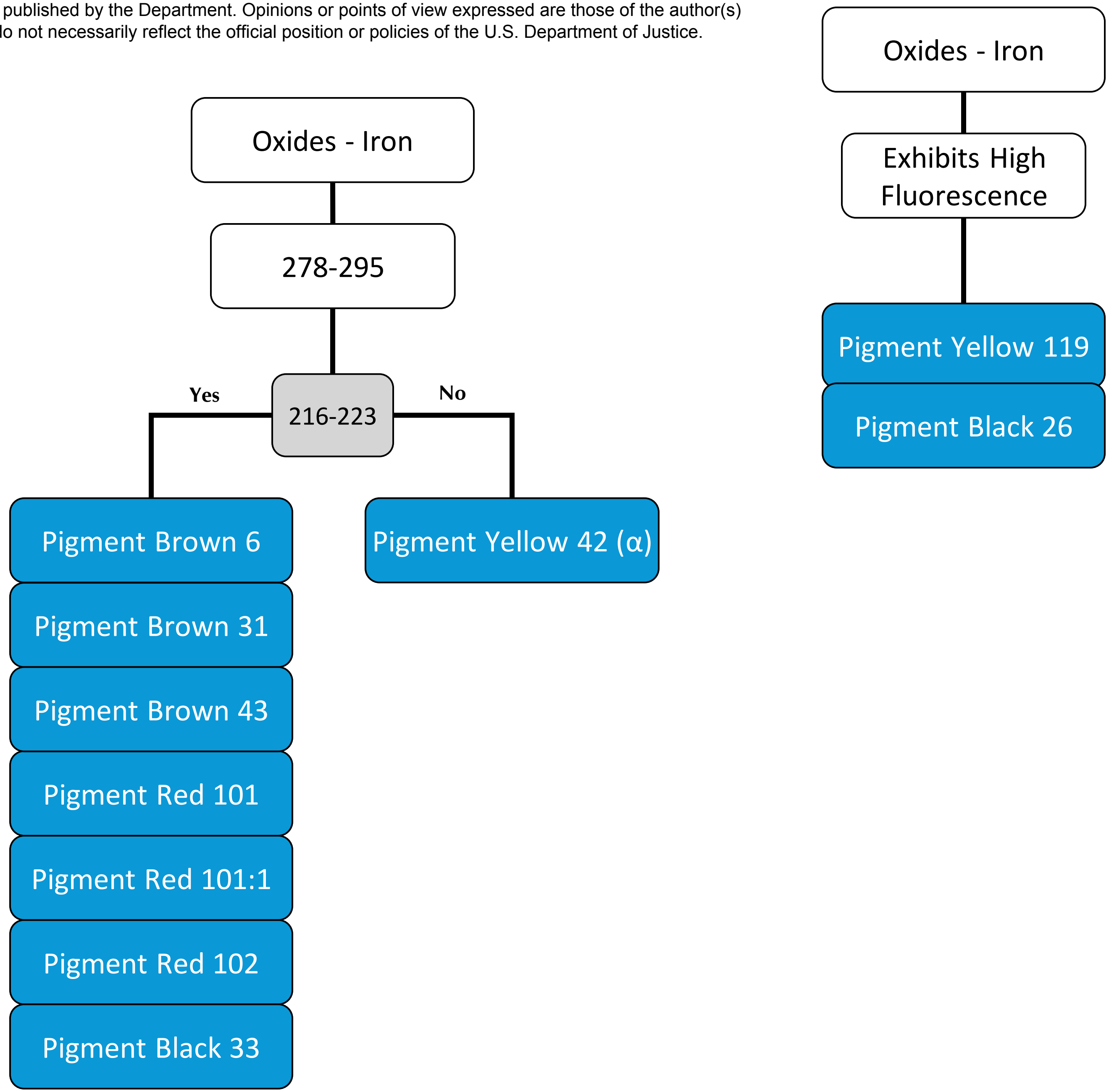


Nitro

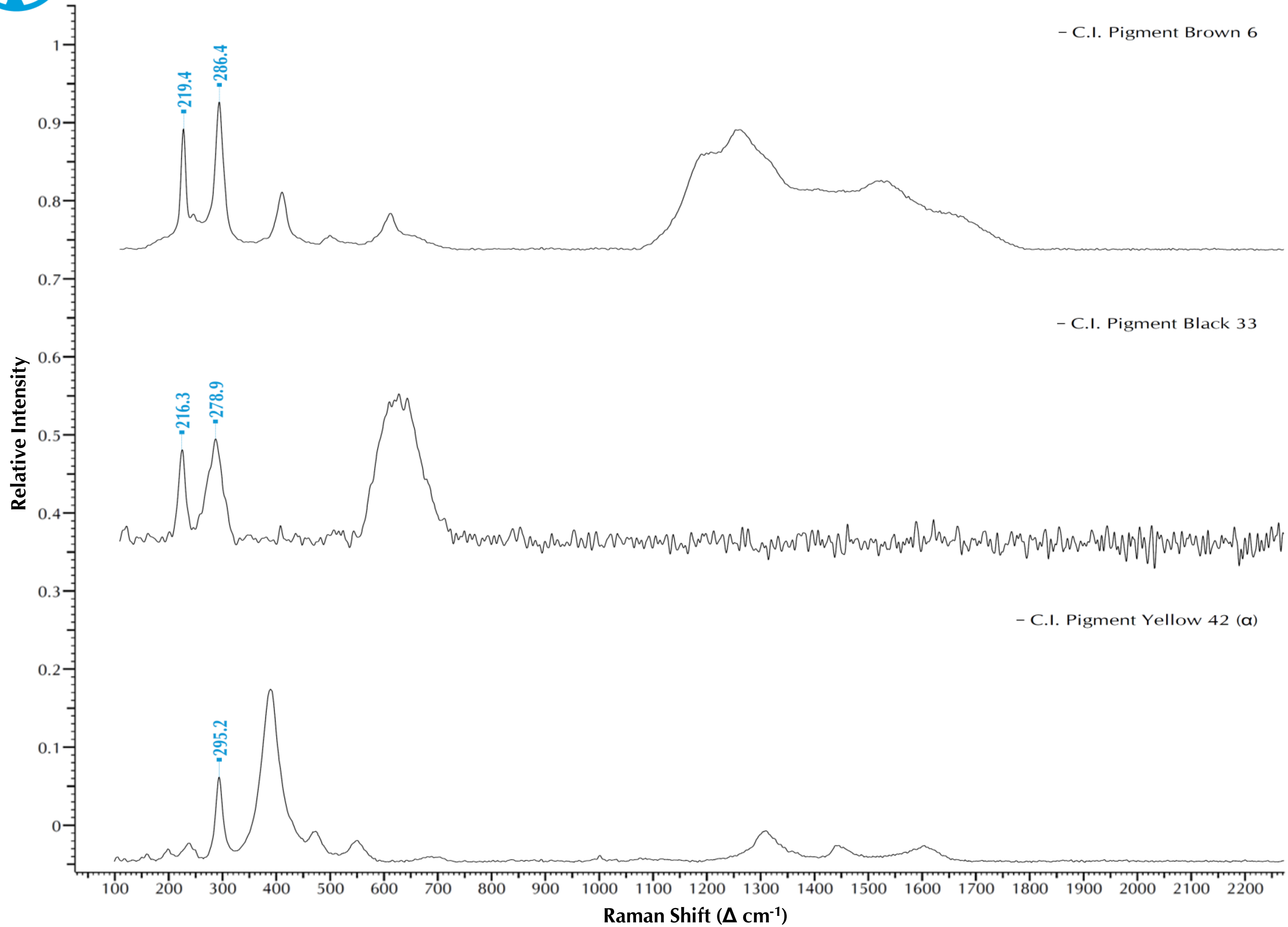


- C.I. Pigment Yellow 40
300.5
1329
Relative Intensity
Raman Shift (Δ cm-1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Oxides - Iron

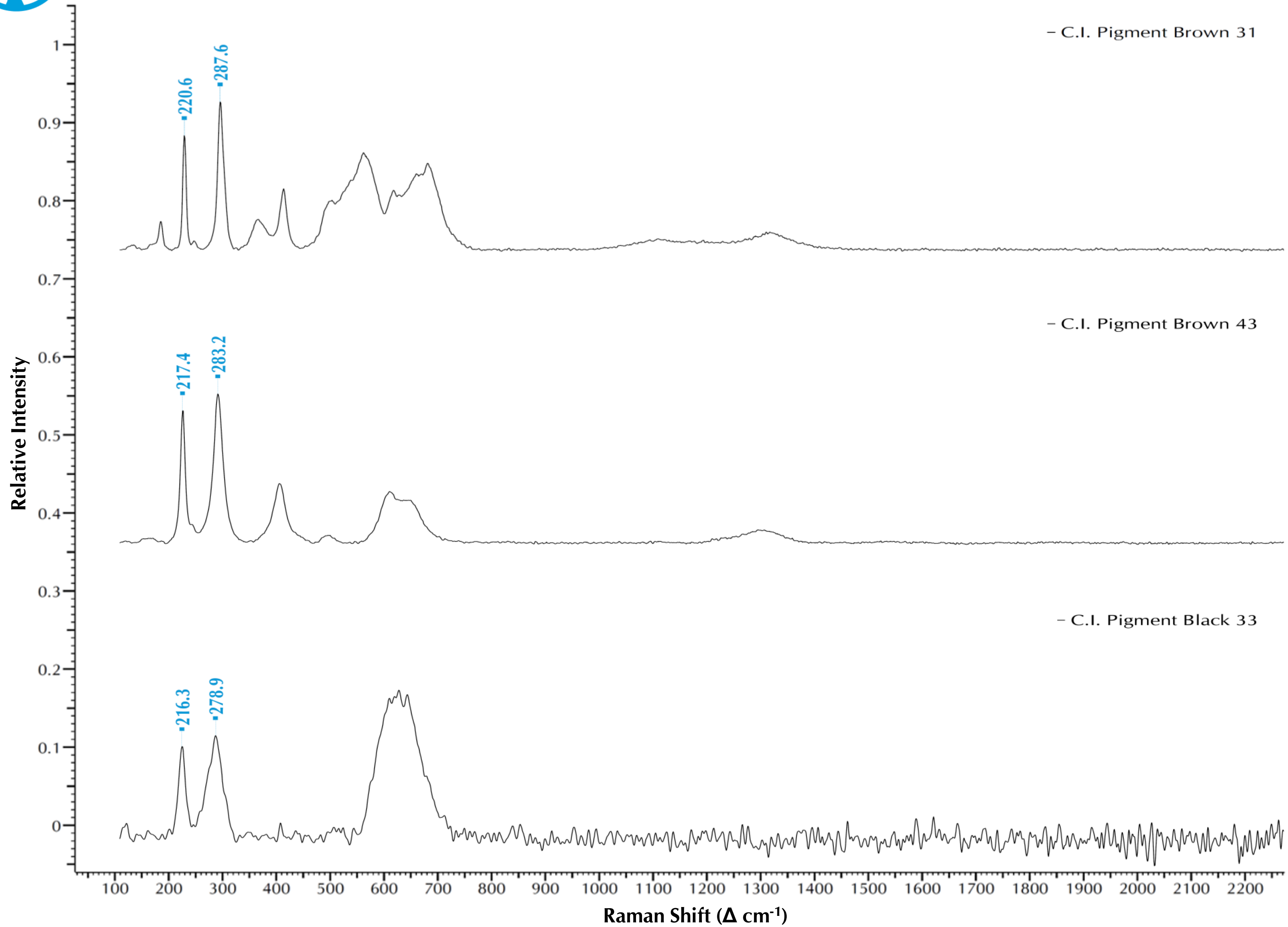

Oxides - Iron
278-295
216-223
Yes
No
Pigment Brown 6
Pigment Brown 31
Pigment Brown 43
Pigment Red 101
Pigment Red 101:1
Pigment Red 102
Pigment Black 33
Pigment Yellow 42 (α)
Oxides - Iron
Exhibits High Fluorescence
Pigment Yellow 119
Pigment Black 26

Oxides - Iron



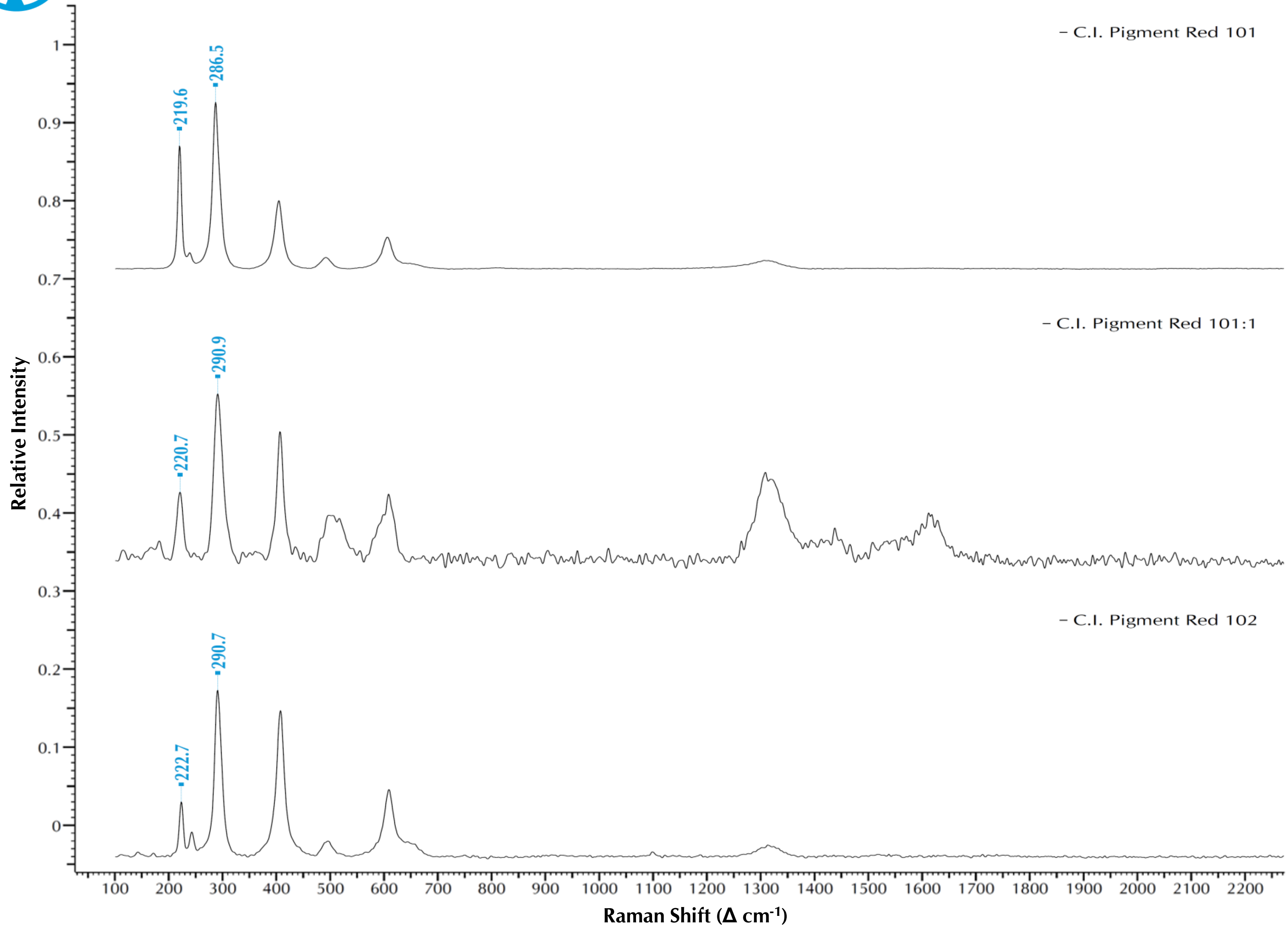
– C.I. Pigment Brown 6
– C.I. Pigment Black 33
– C.I. Pigment Yellow 42 (α)
219.4
286.4
216.3
278.9
295.2
Relative Intensity
Raman Shift (Δ cm⁻¹)

Oxides - Iron



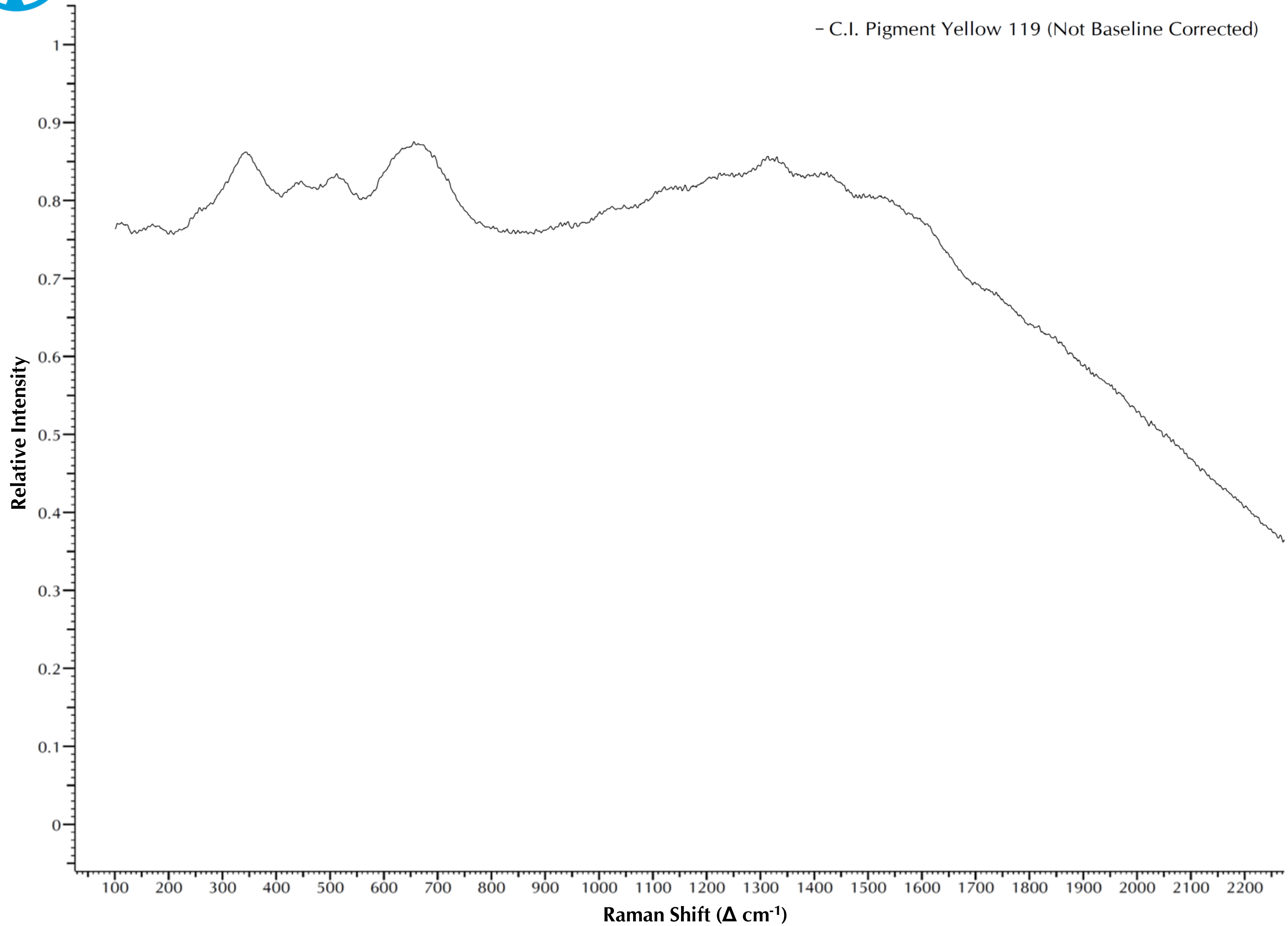
– C.I. Pigment Brown 31
– C.I. Pigment Brown 43
– C.I. Pigment Black 33
220.6
287.6
217.4
283.2
216.3
278.9
Relative Intensity
Raman Shift (Δ cm-1)

Oxides - Iron



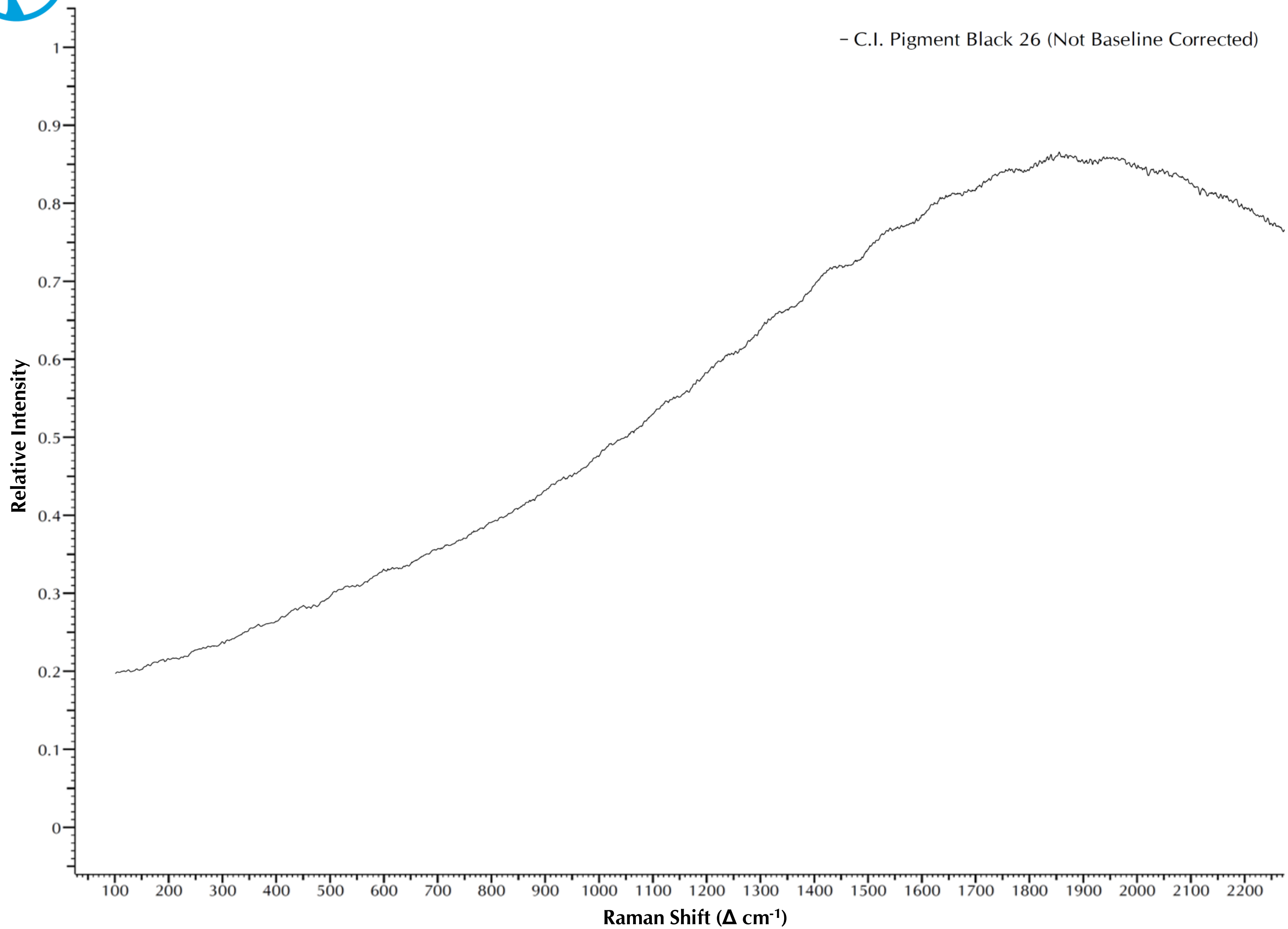
– C.I. Pigment Red 101
– C.I. Pigment Red 101:1
– C.I. Pigment Red 102
219.6
286.5
220.7
290.9
222.7
290.7
Relative Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Oxides - Iron



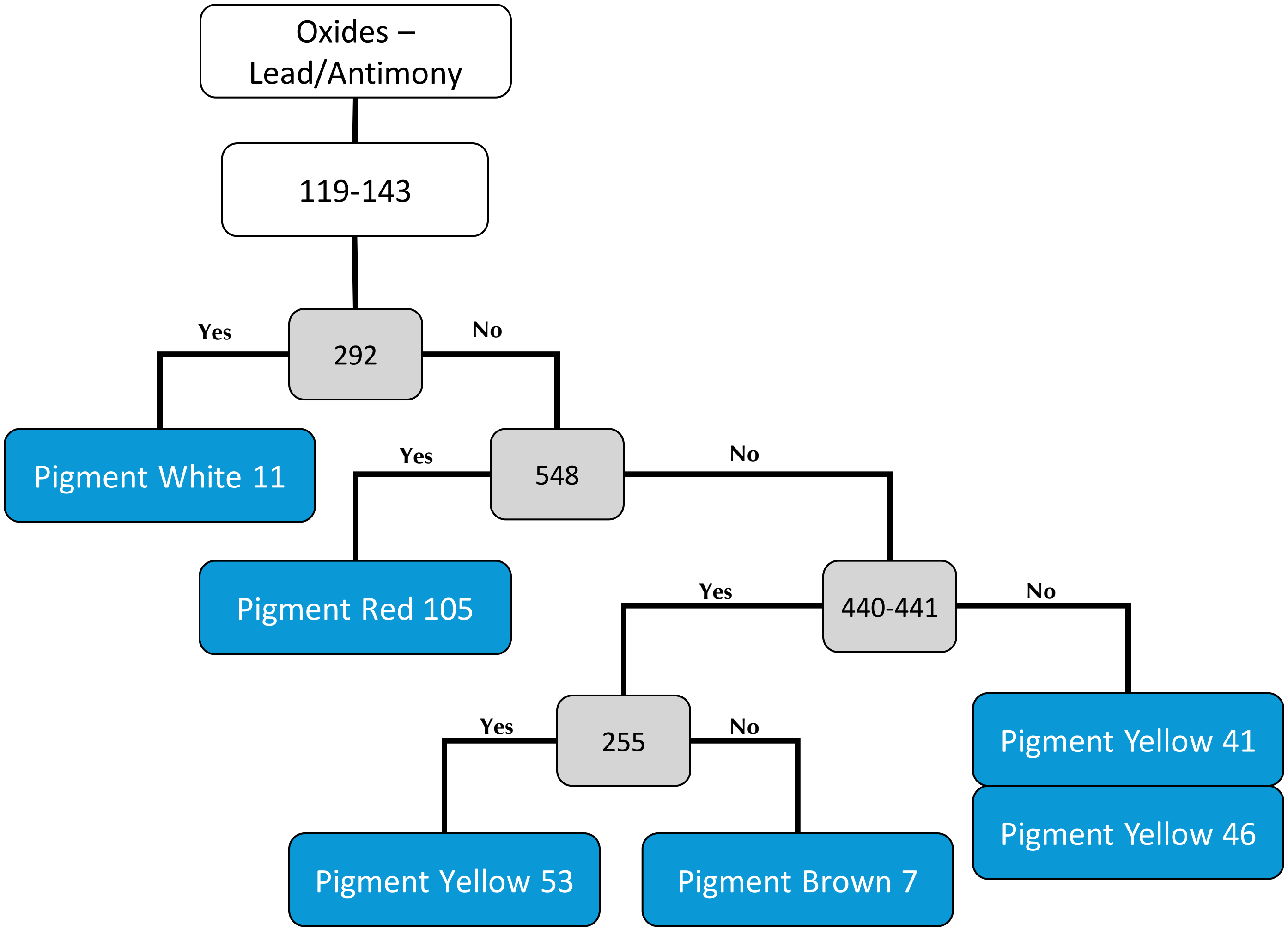
– C.I. Pigment Yellow 119 (Not Baseline Corrected)
Relative Intensity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Raman Shift (Δ cm-1)
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Oxides - Iron

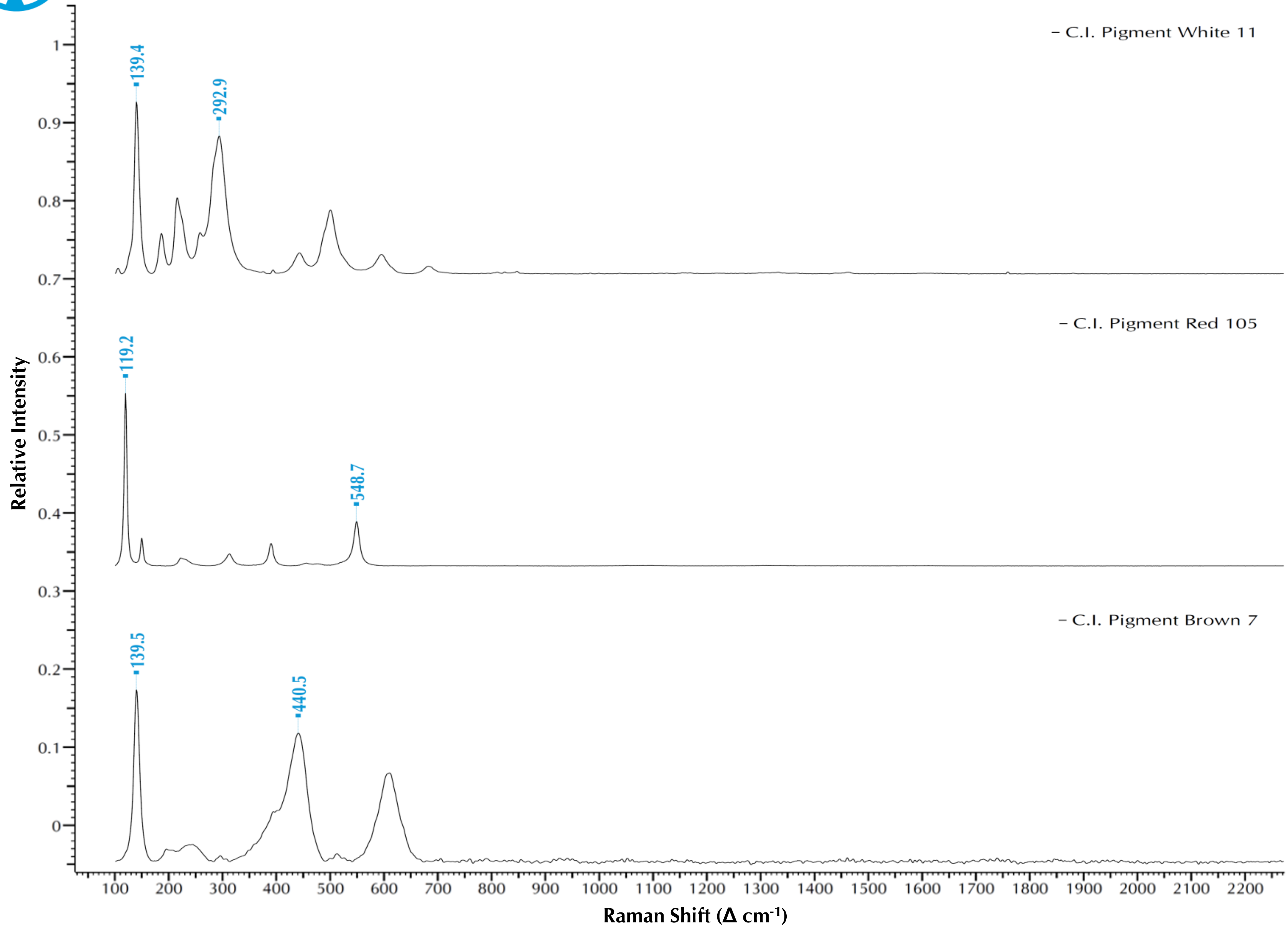


– C.I. Pigment Black 26 (Not Baseline Corrected)
Relative Intensity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Raman Shift (Δ cm-1)
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

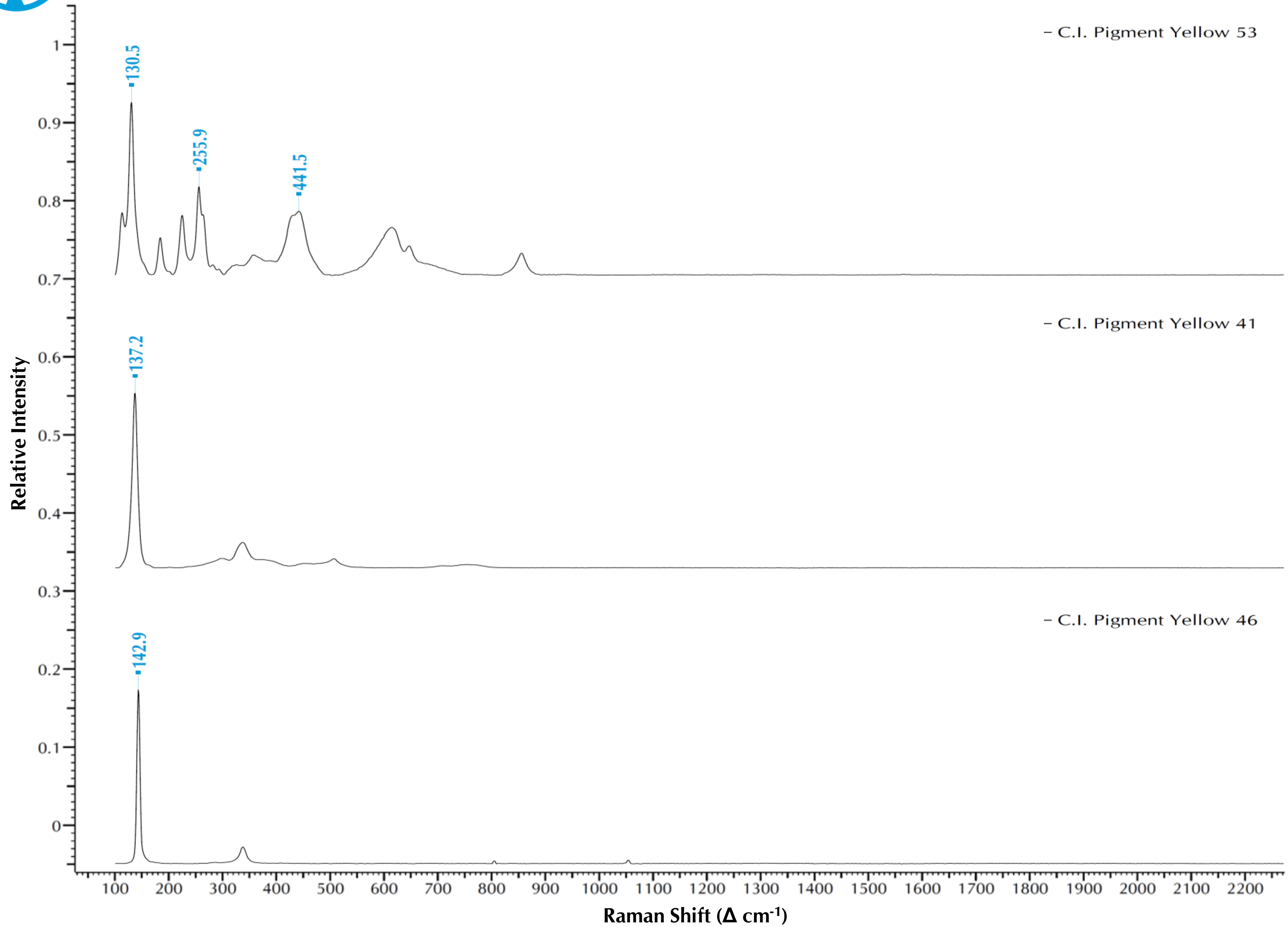
Oxides – Lead/Antimony



Oxides – Lead/Antimony



Oxides – Lead/Antimony



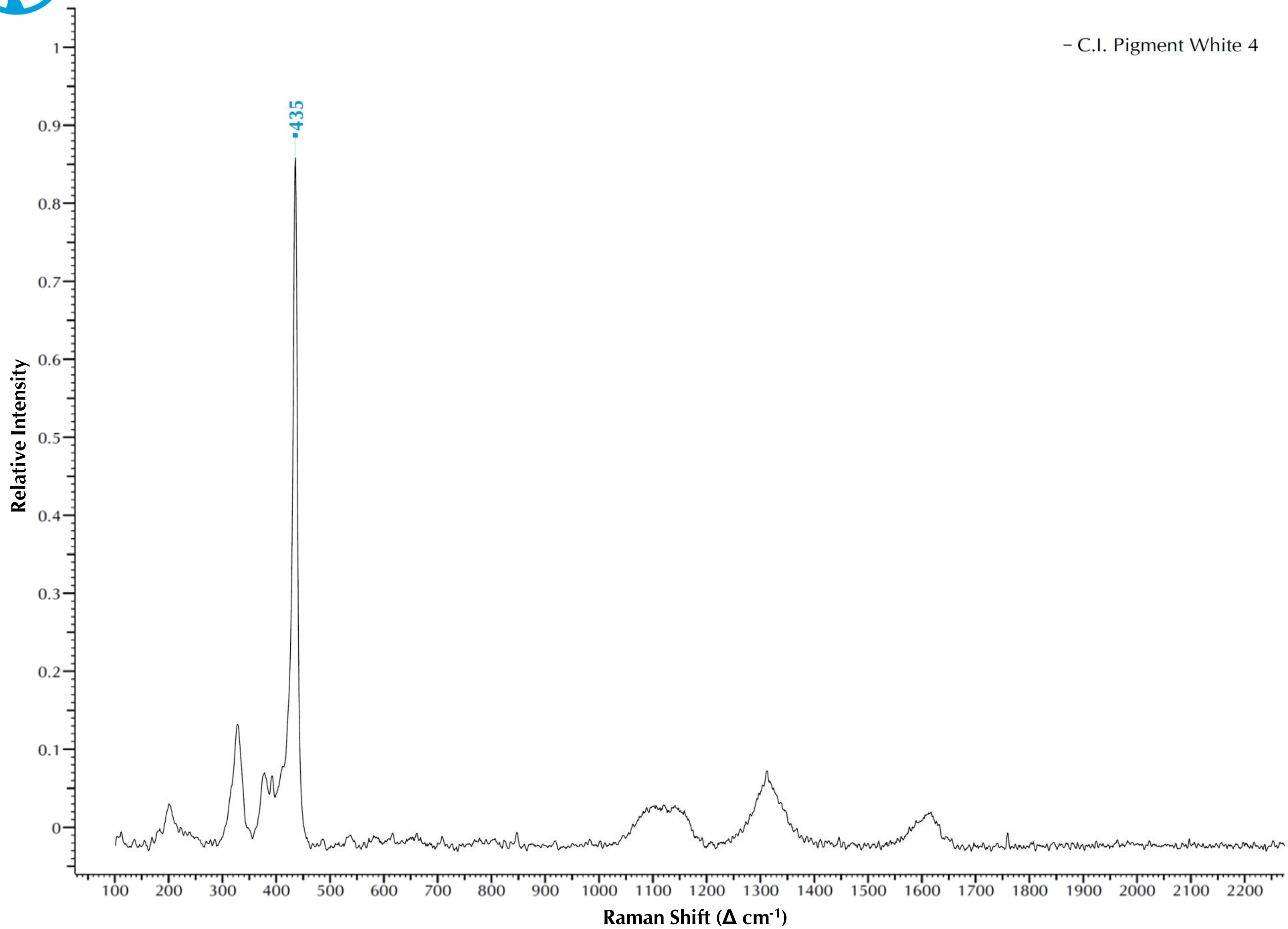
Oxides - Zinc

Oxides - Zinc

435

Pigment White 4

Oxides – Zinc



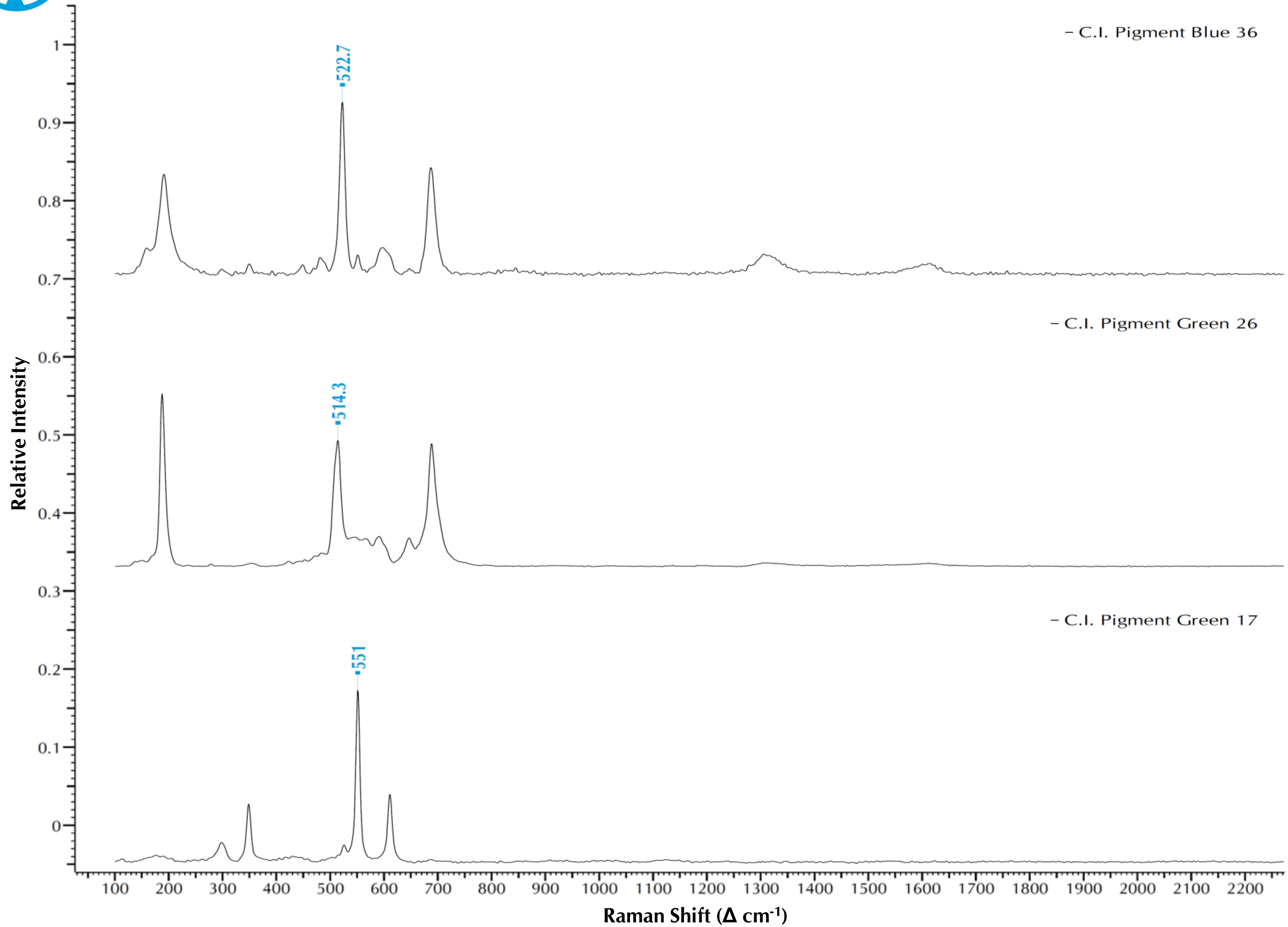
– C.I. Pigment White 4
435
Relative Intensity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
Raman Shift (Δ cm-1)

Oxides - other

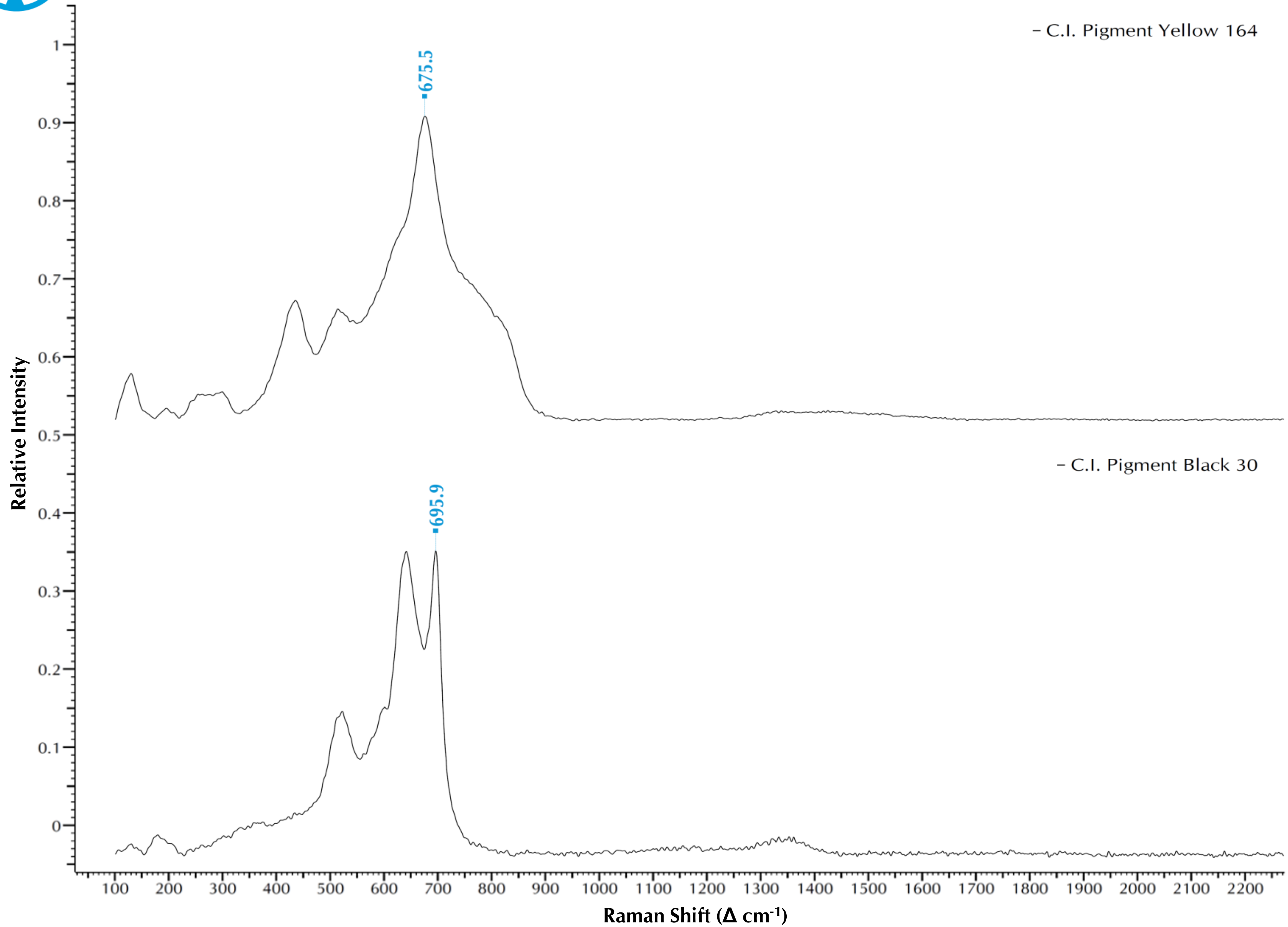
- Oxide - other
  - 514-676
    - Pigment Yellow 164
    - Pigment Black 30
    - Pigment Green 26
    - Pigment Blue 36
    - Pigment Green 17

- Oxides - other
  - Exhibits High Fluorescence
    - Pigment Brown 24
    - Pigment Green 18
    - Pigment Yellow 162

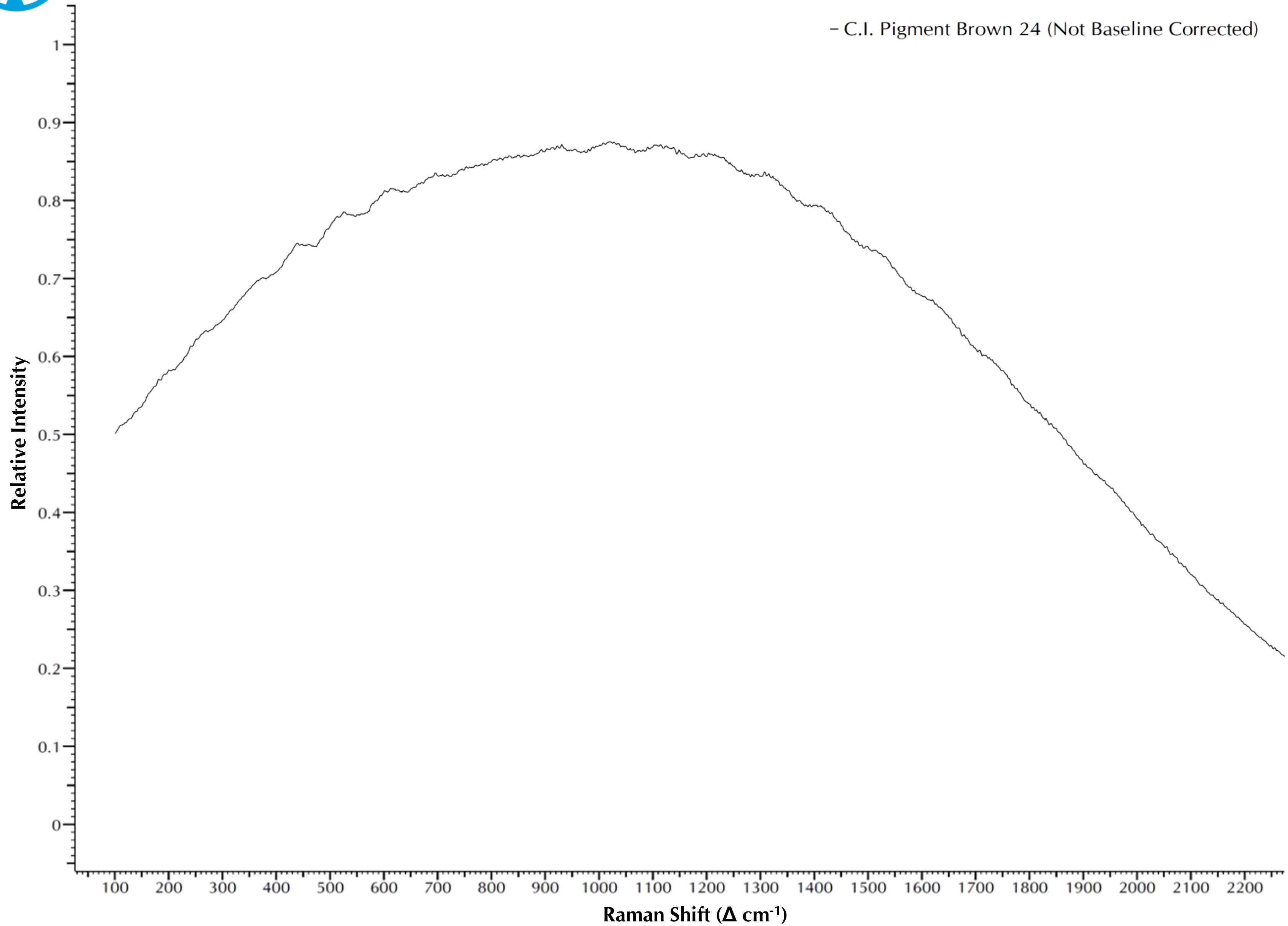
Oxides – other



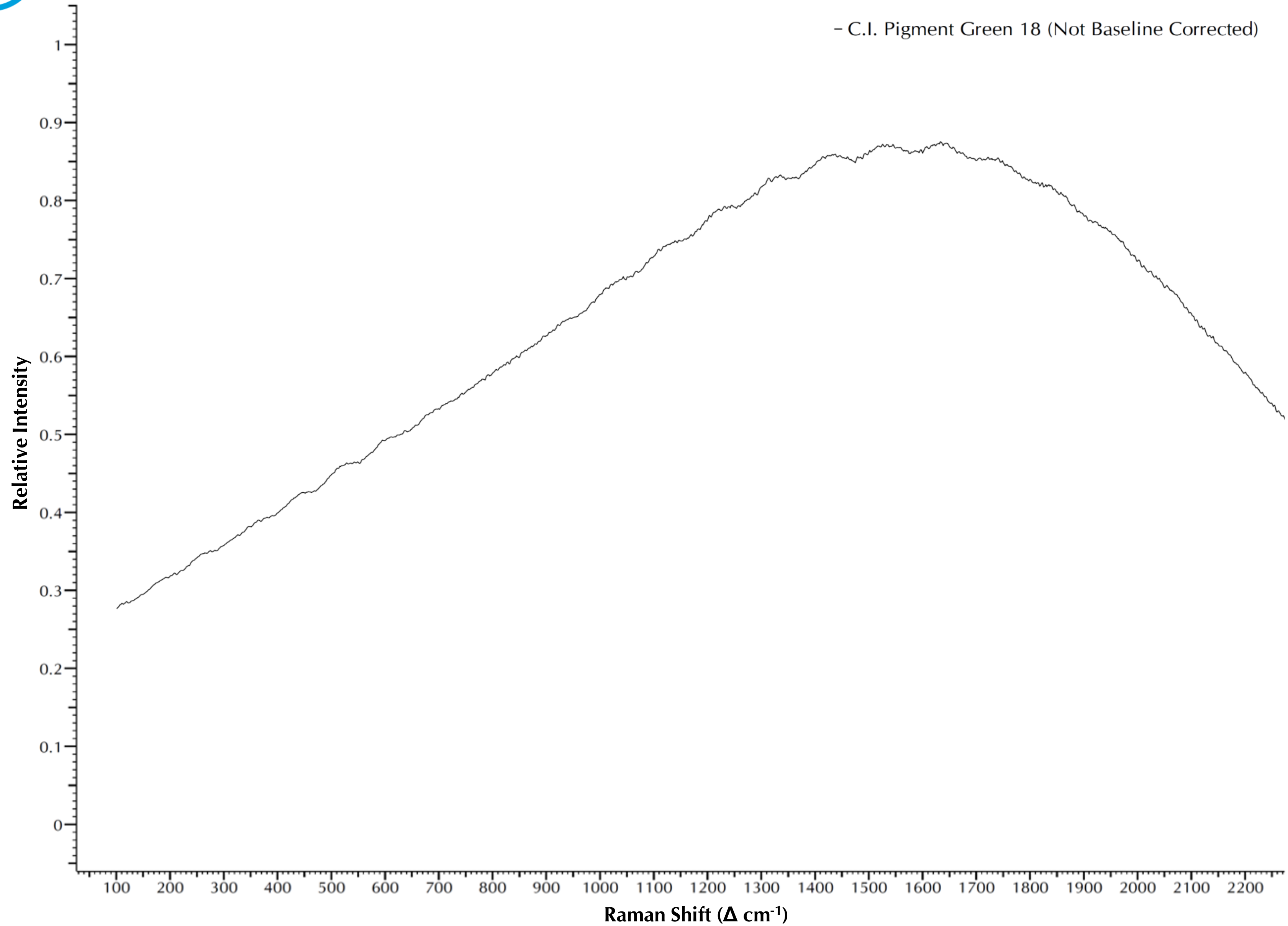
Oxides – other



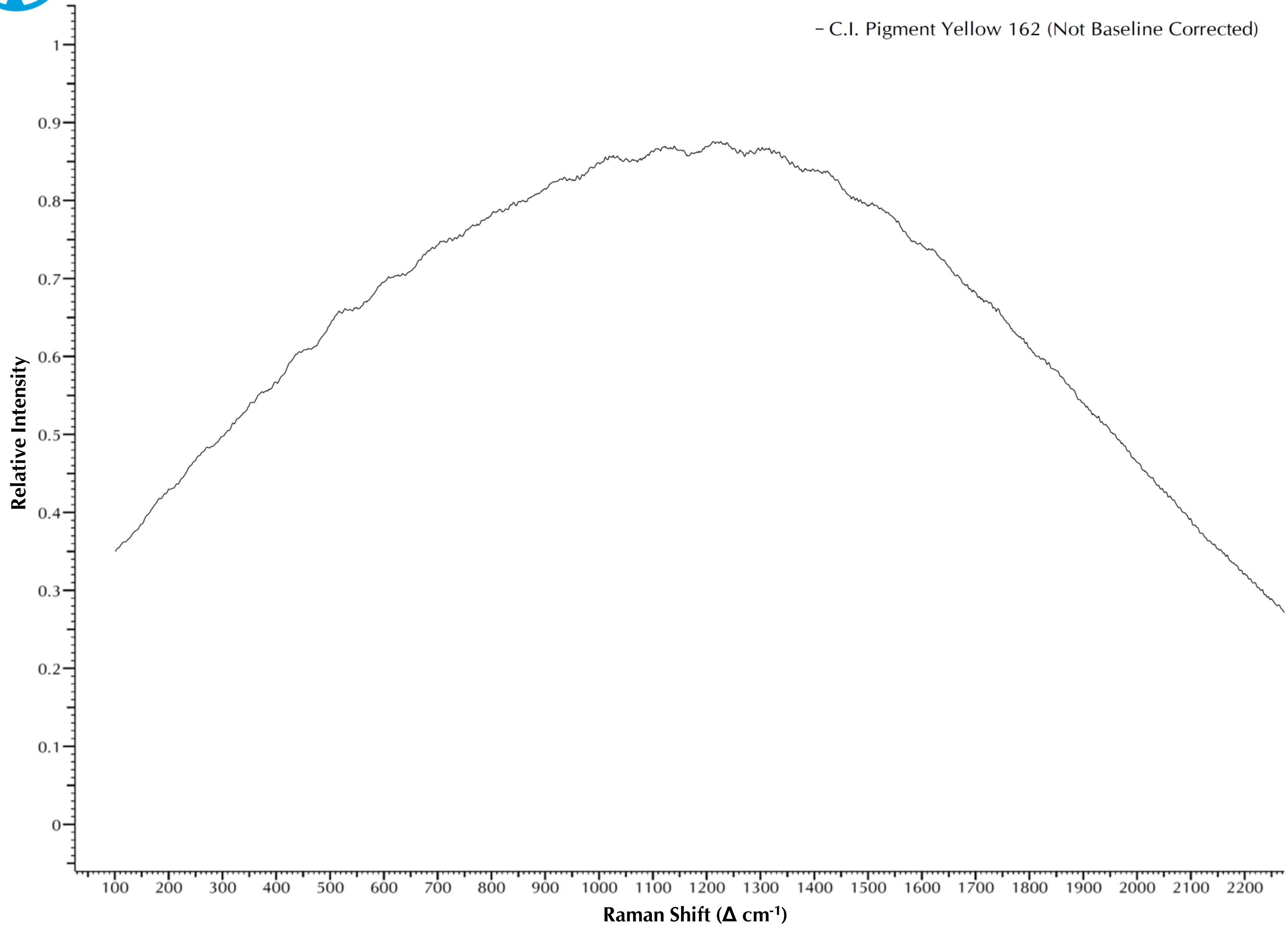
Oxides – other



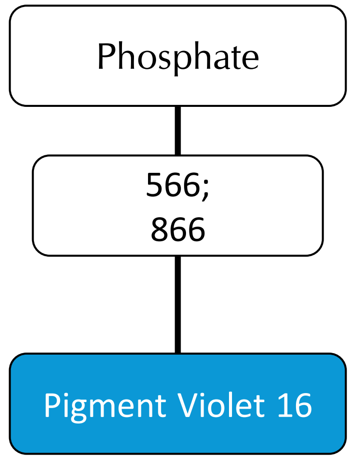
Oxides – other

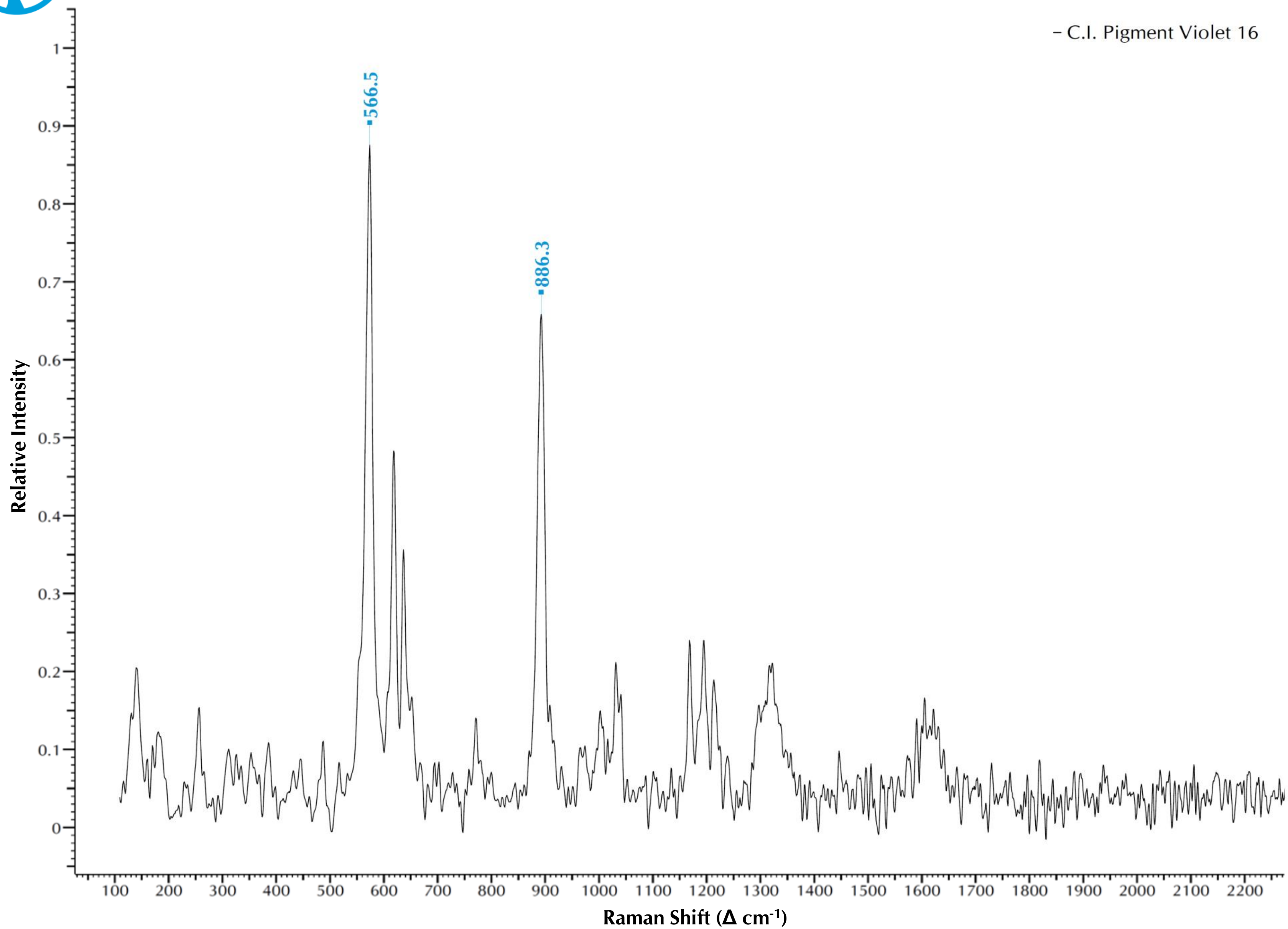


Oxides – other



Phosphate





- C.I. Pigment Violet 16
566.5
886.3
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Silicate (1 of 2)

Silicate

Exhibits High Fluorescence

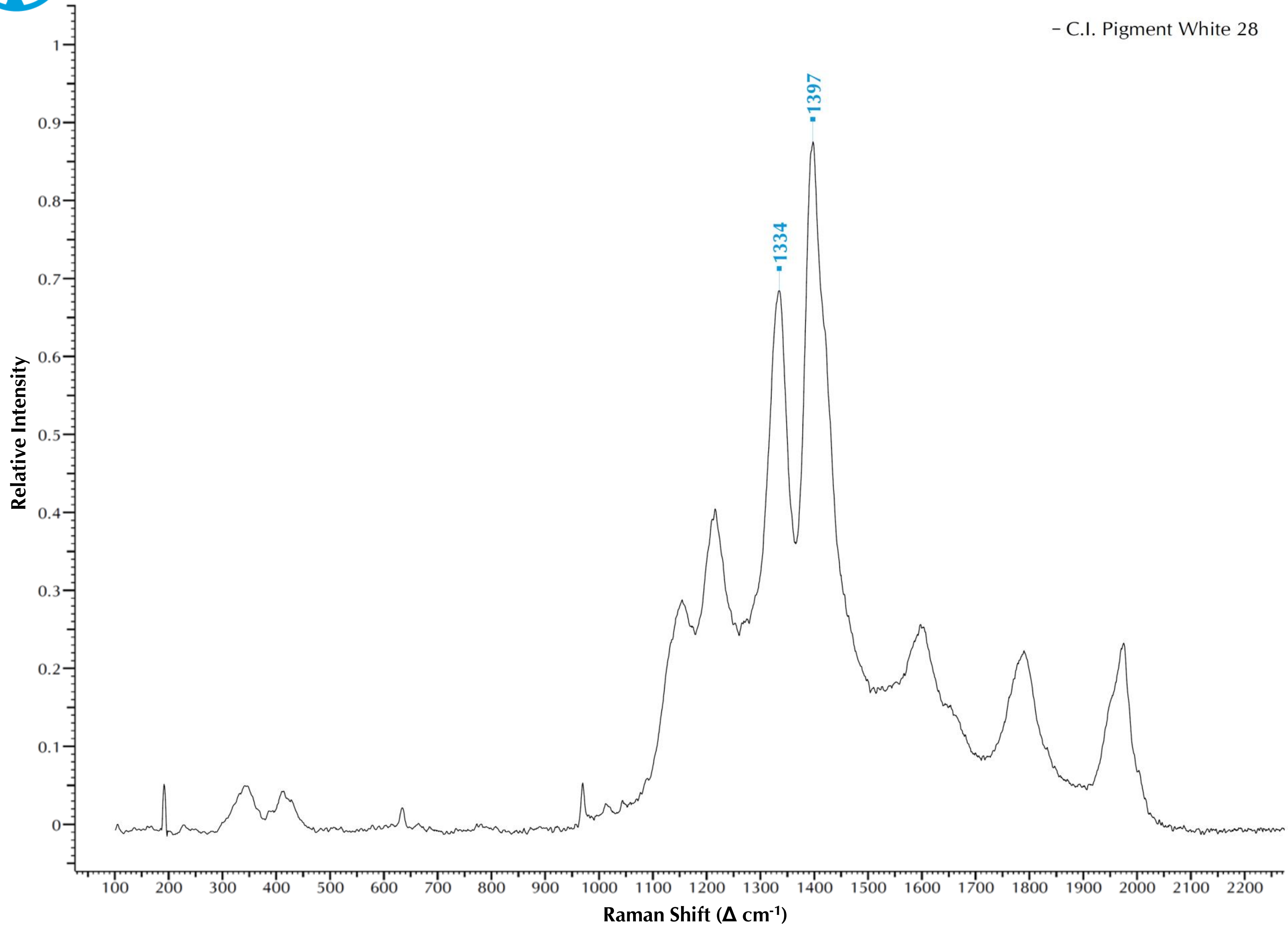
Pigment Blue 31

Silicate

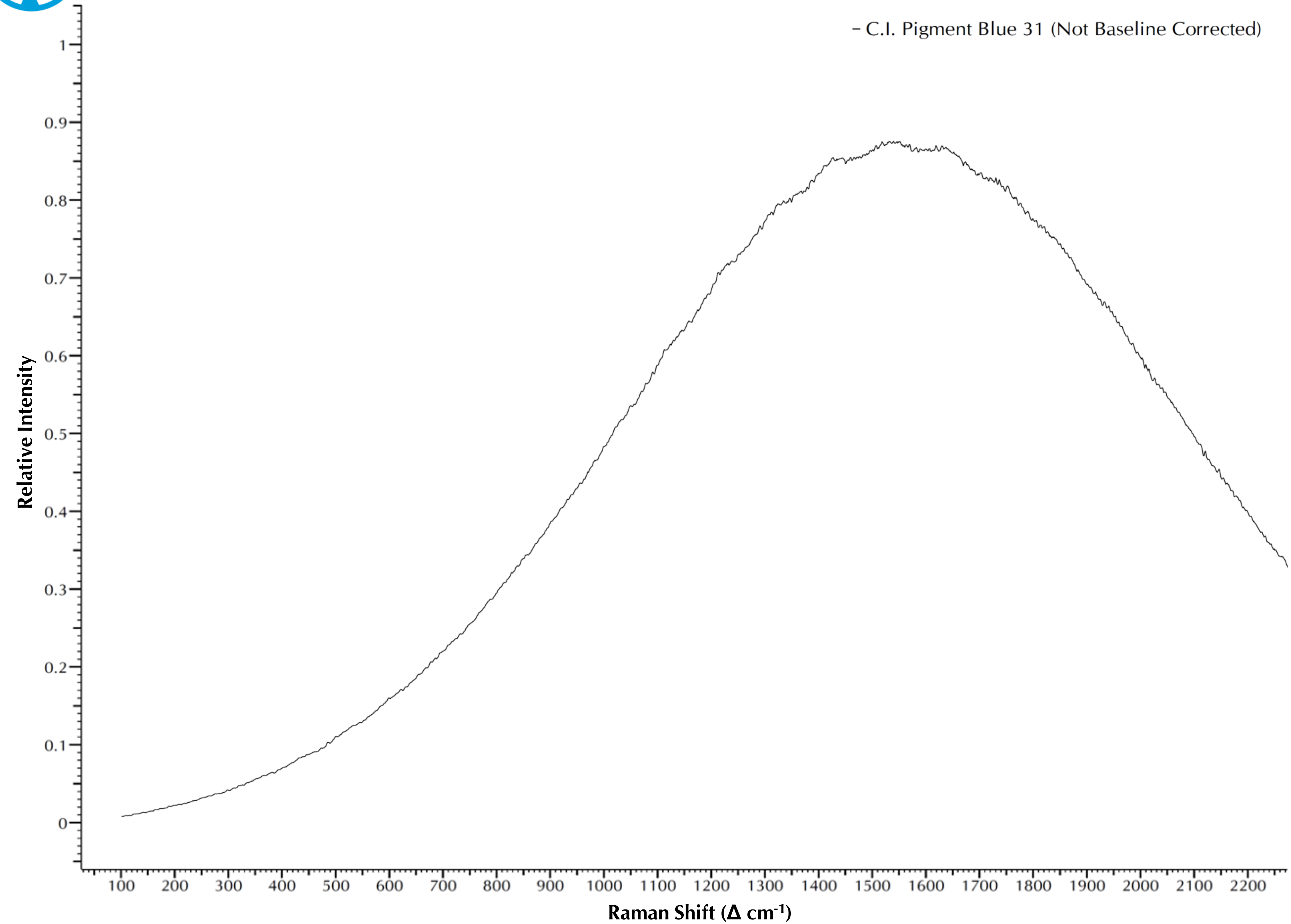
1397;
1334

Pigment White 28

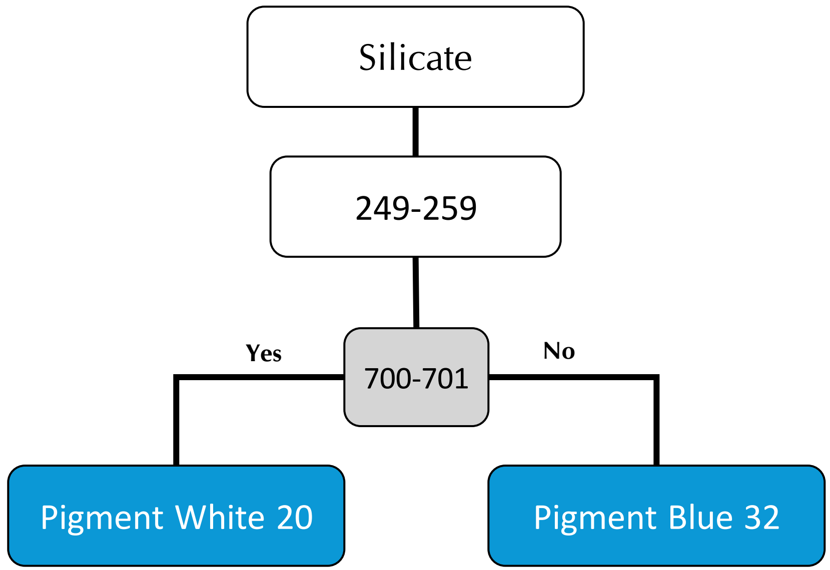
Silicate (1 of 2)



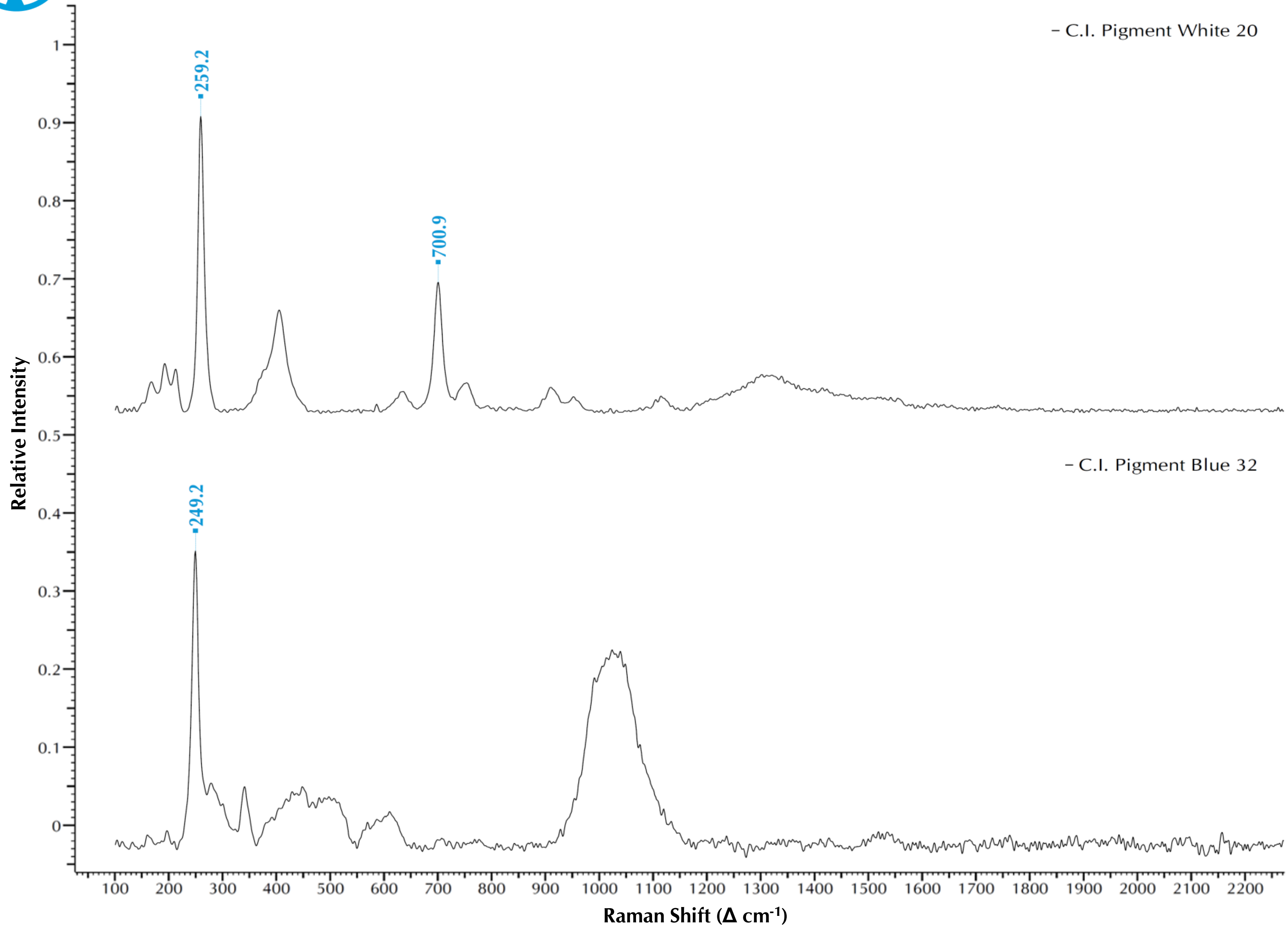
Silicates – Not Baseline Corrected



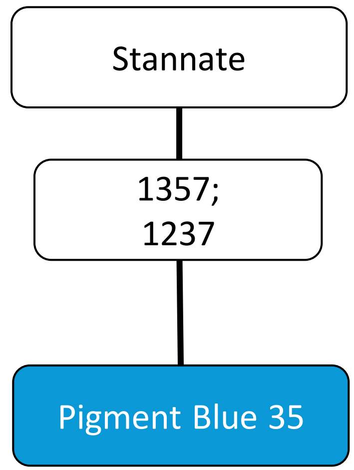
Silicate (2 of 2)



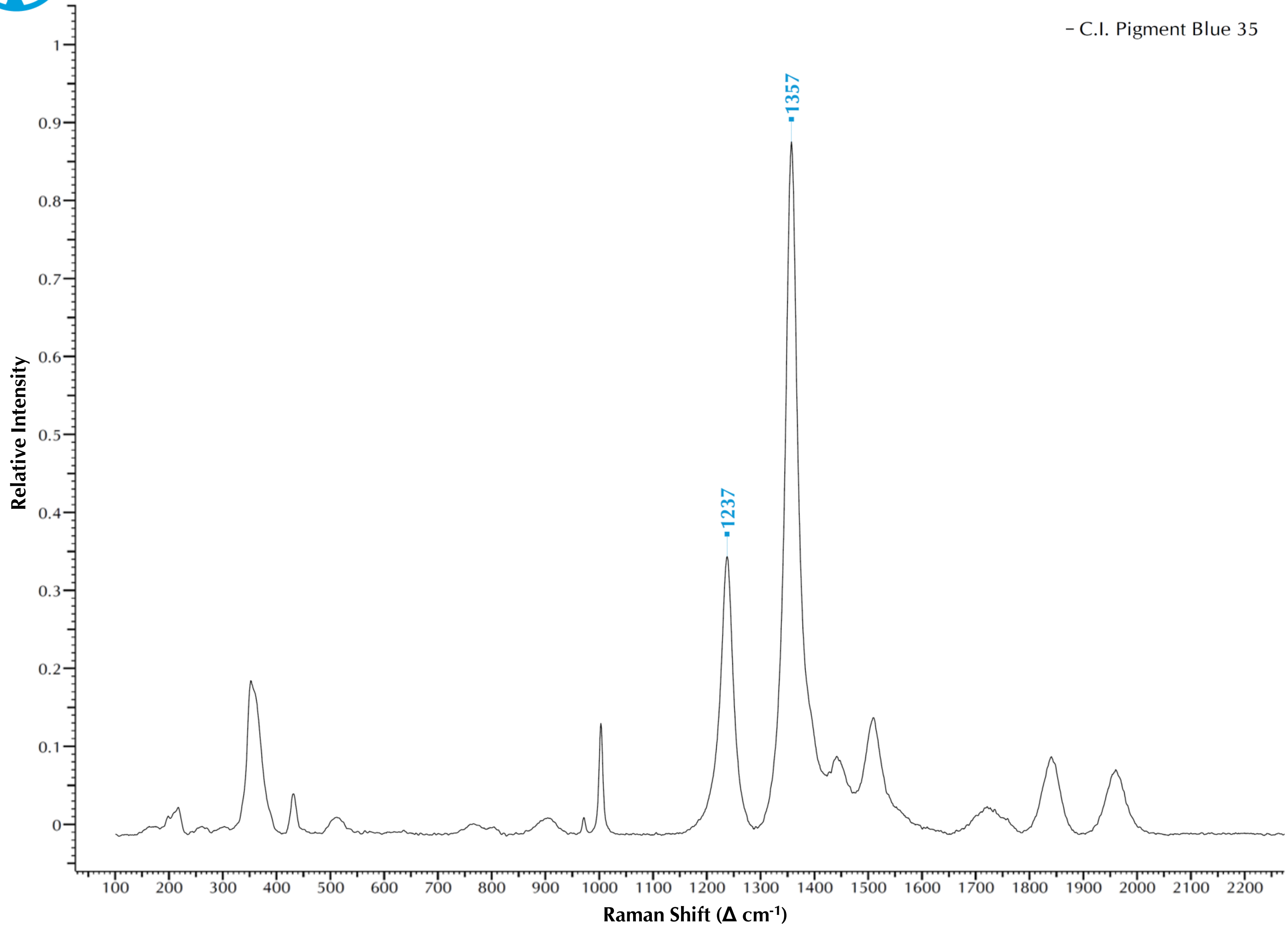
Silicate (2 of 2)



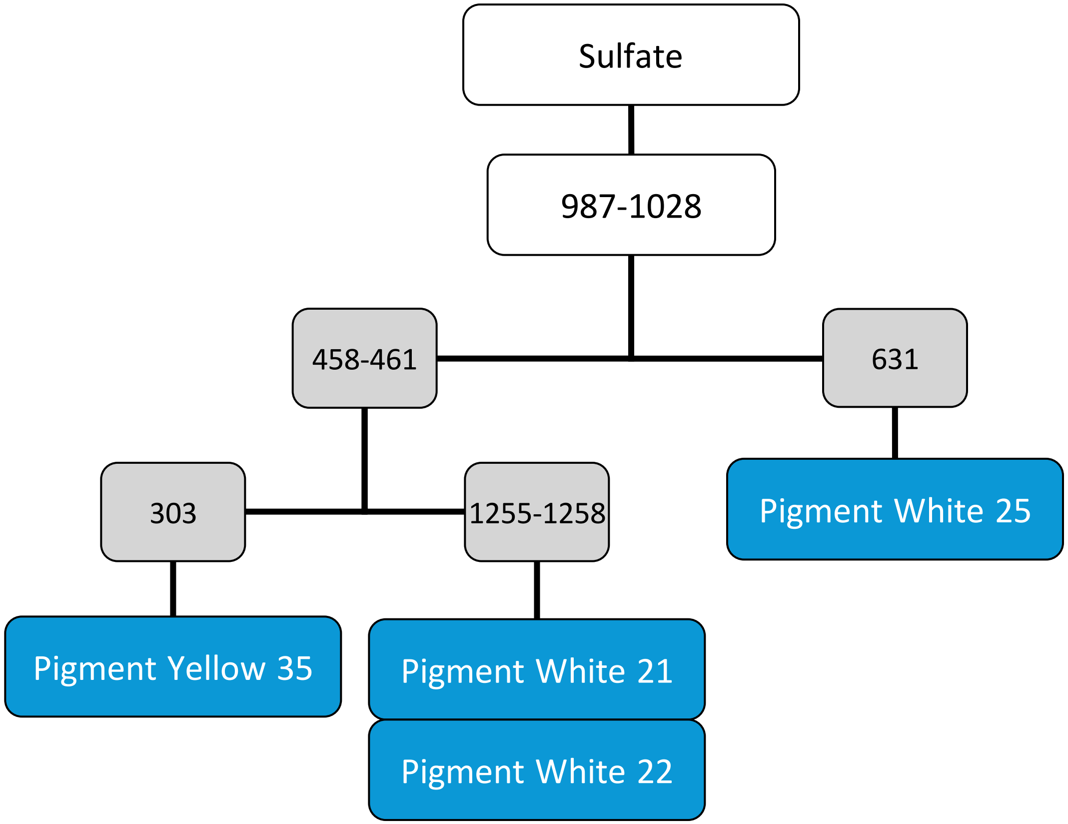
Stannate



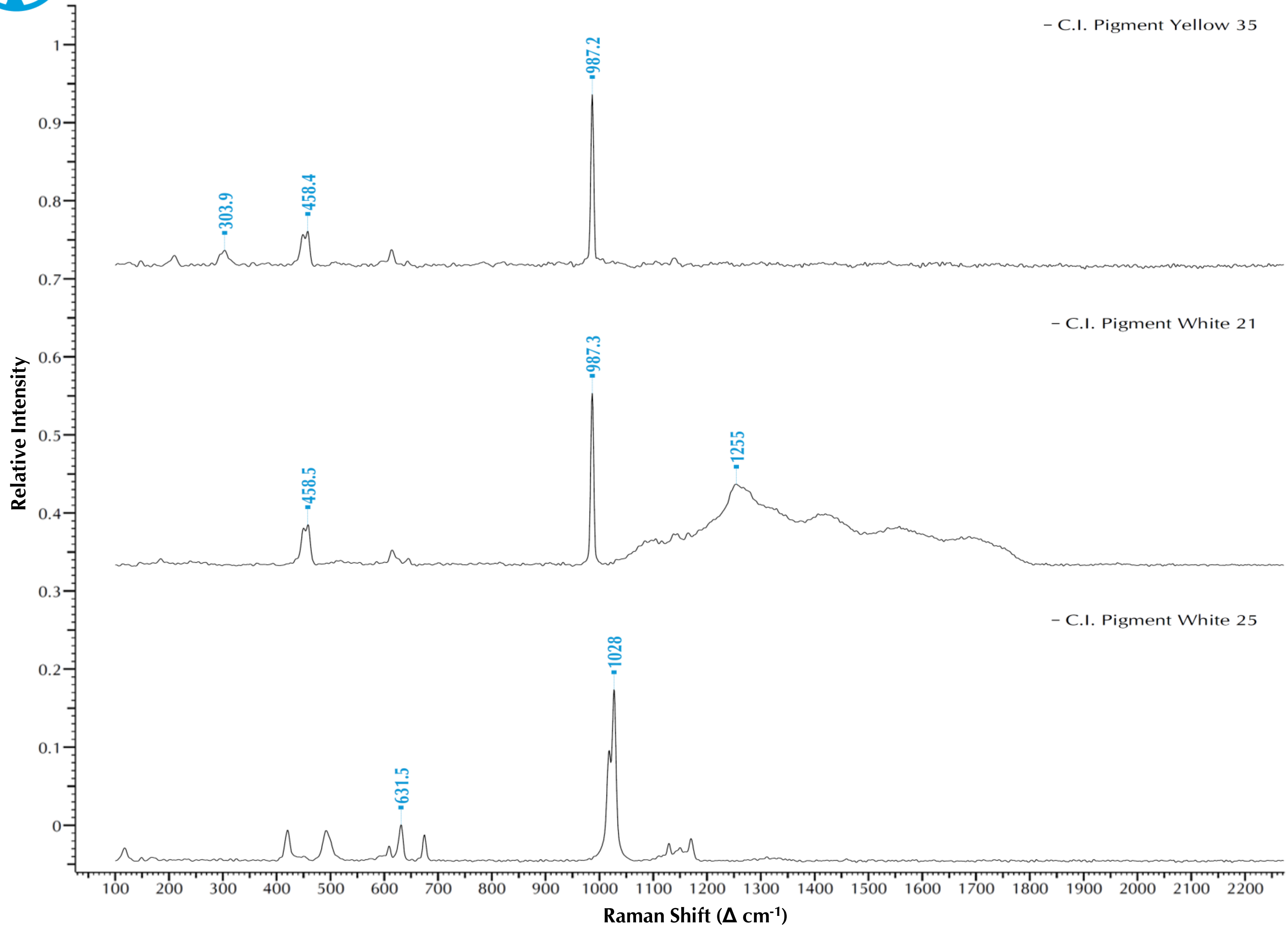
Stannate


- C.I. Pigment Blue 35
1357
1237
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Sulfate

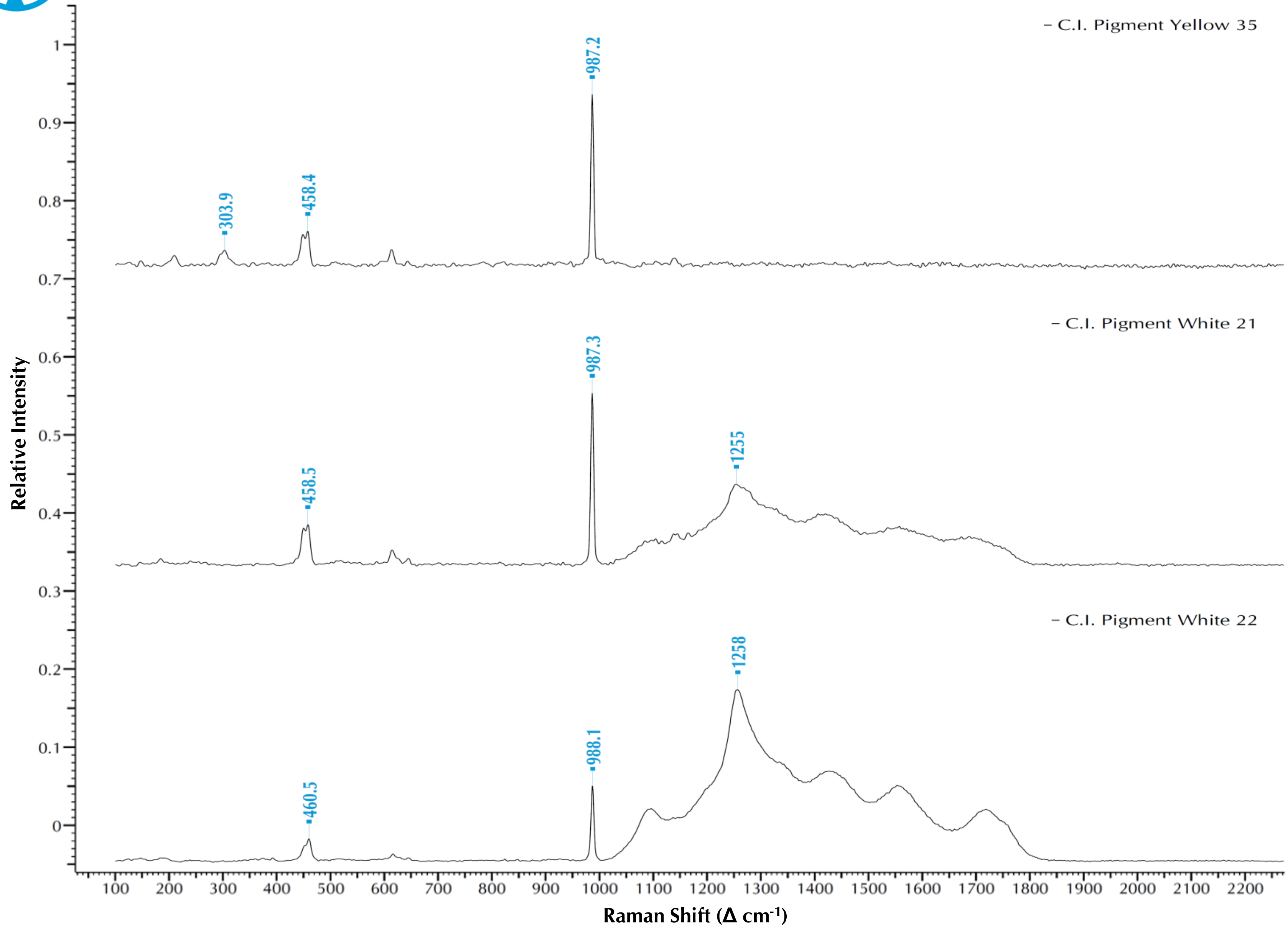

Sulfate
987-1028
458-461
631
303
1255-1258
Pigment White 25
Pigment Yellow 35
Pigment White 21
Pigment White 22

Sulfate



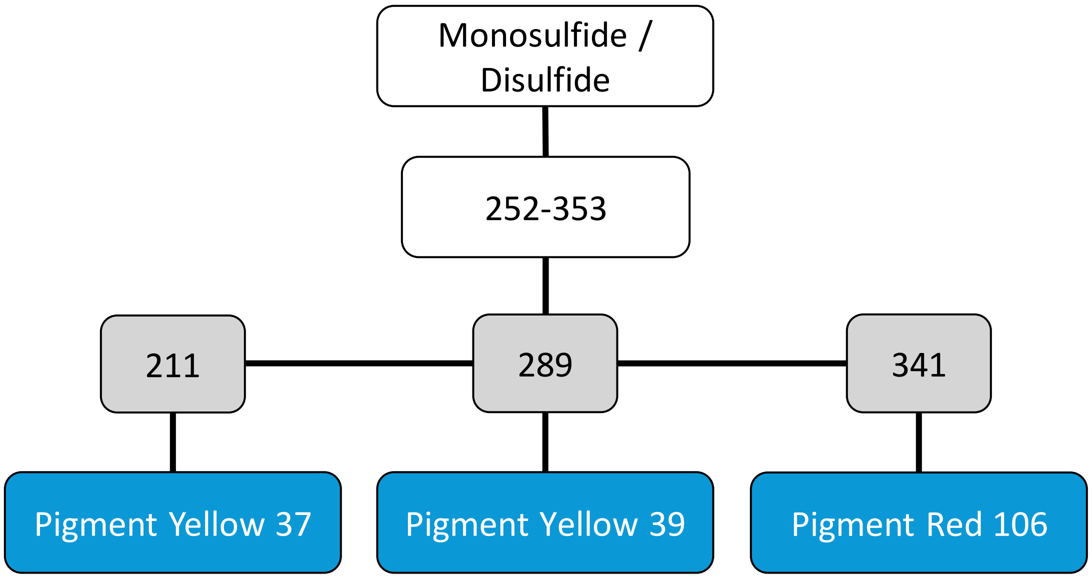
– C.I. Pigment Yellow 35
– C.I. Pigment White 21
– C.I. Pigment White 25
303.9
458.4
987.2
458.5
987.3
1255
631.5
1028
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

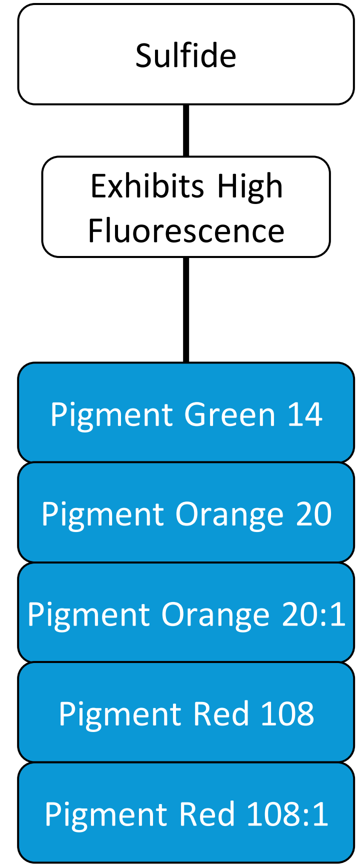
Sulfate



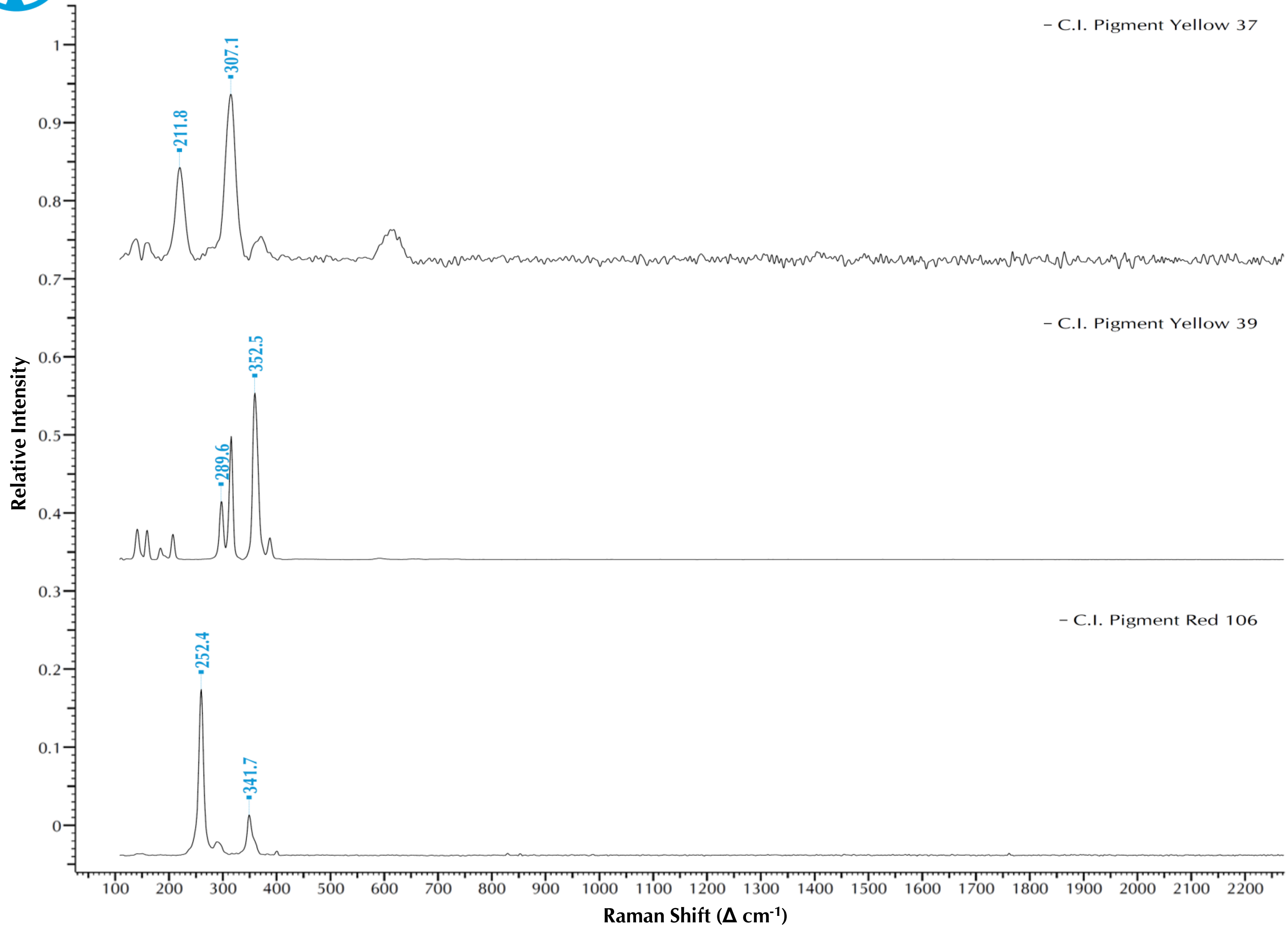
C.I. Pigment Yellow 35
C.I. Pigment White 21
C.I. Pigment White 22
303.9
458.4
987.2
458.5
987.3
1255
460.5
988.1
1258
Relative Intensity
Raman Shift (Δ cm-1)

Sulfide – monosulfide/disulfide

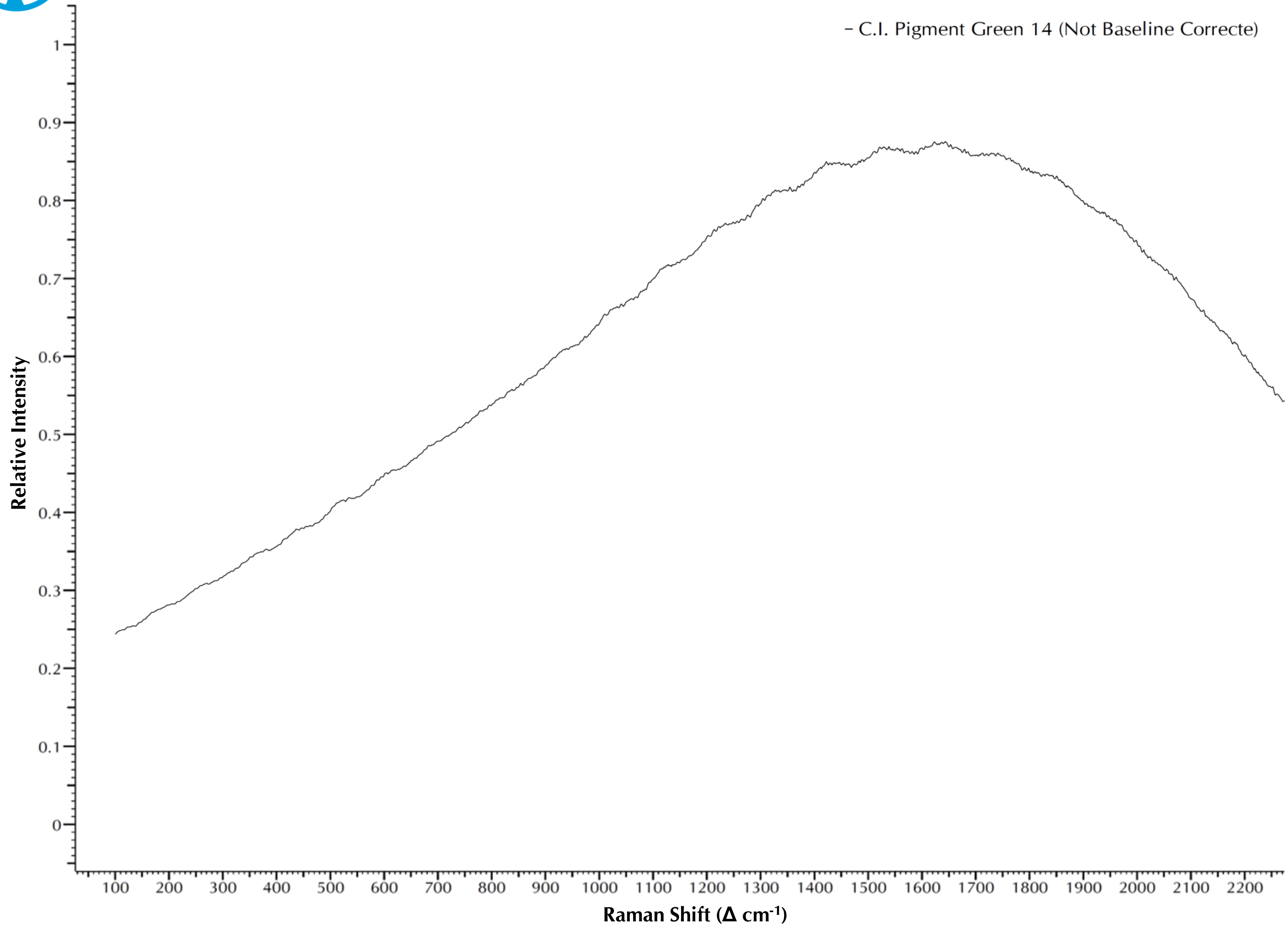




Sulfide – monosulfide/disulfide



Sulfide – monosulfide/disulfide



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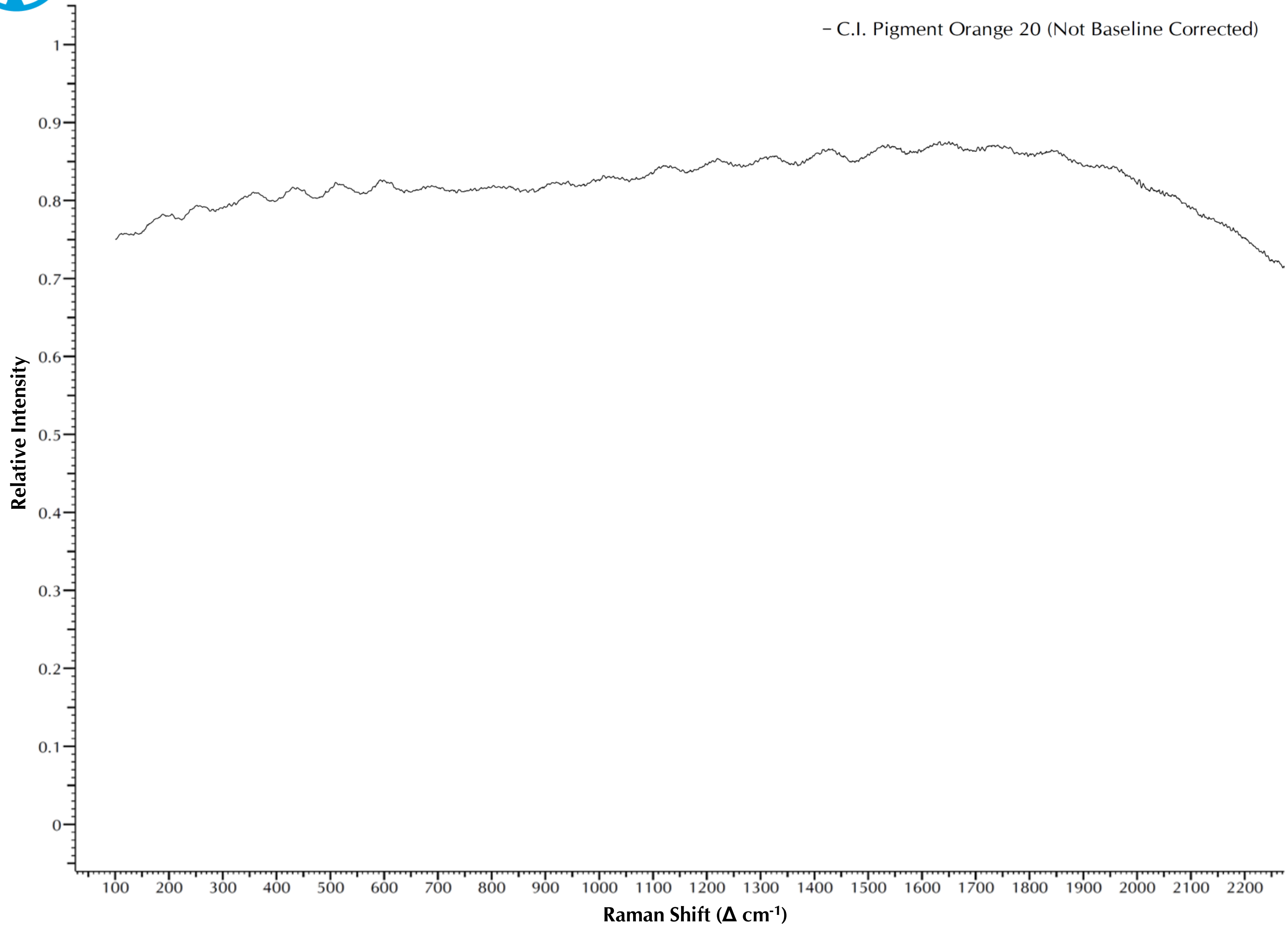
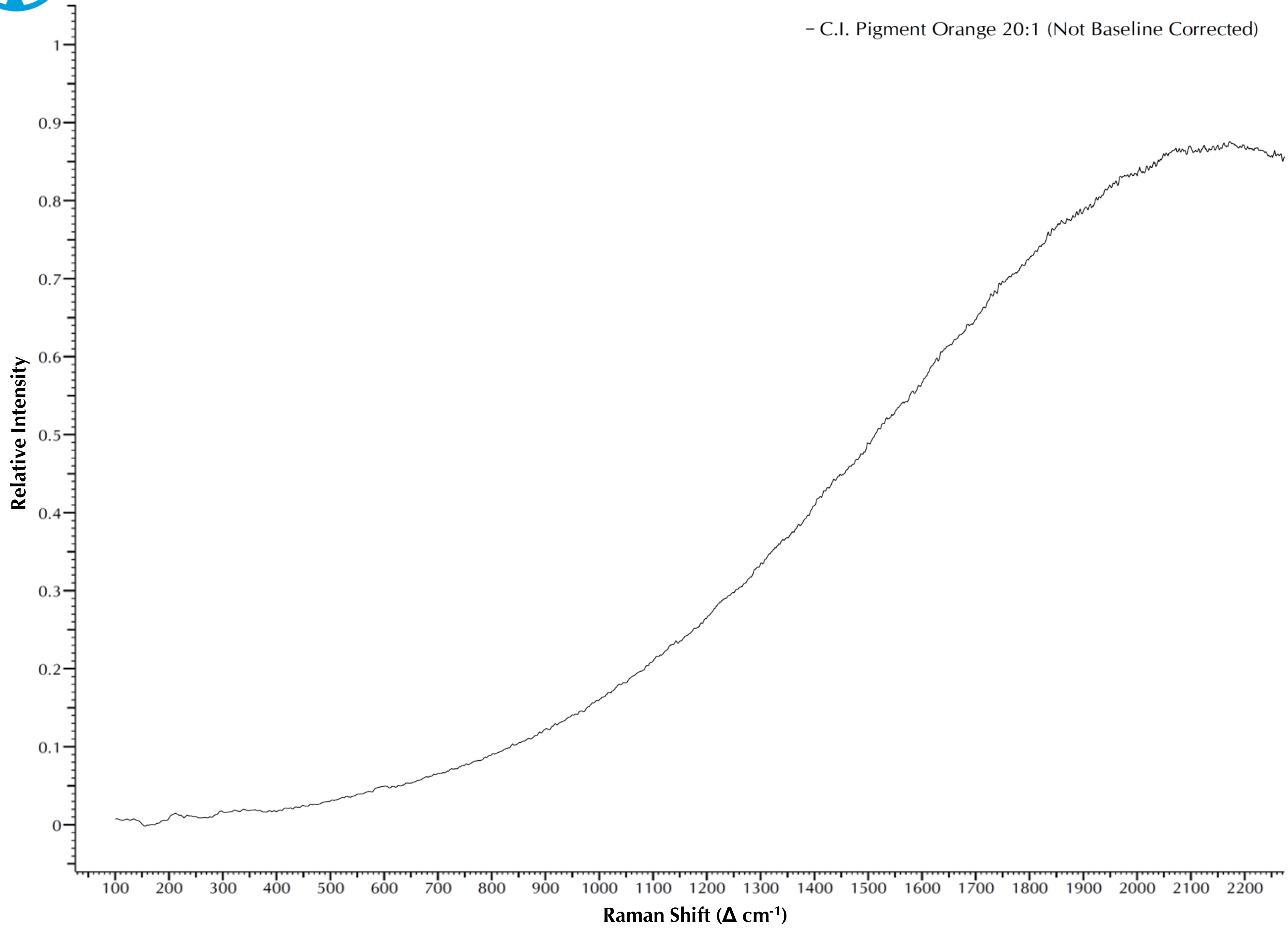
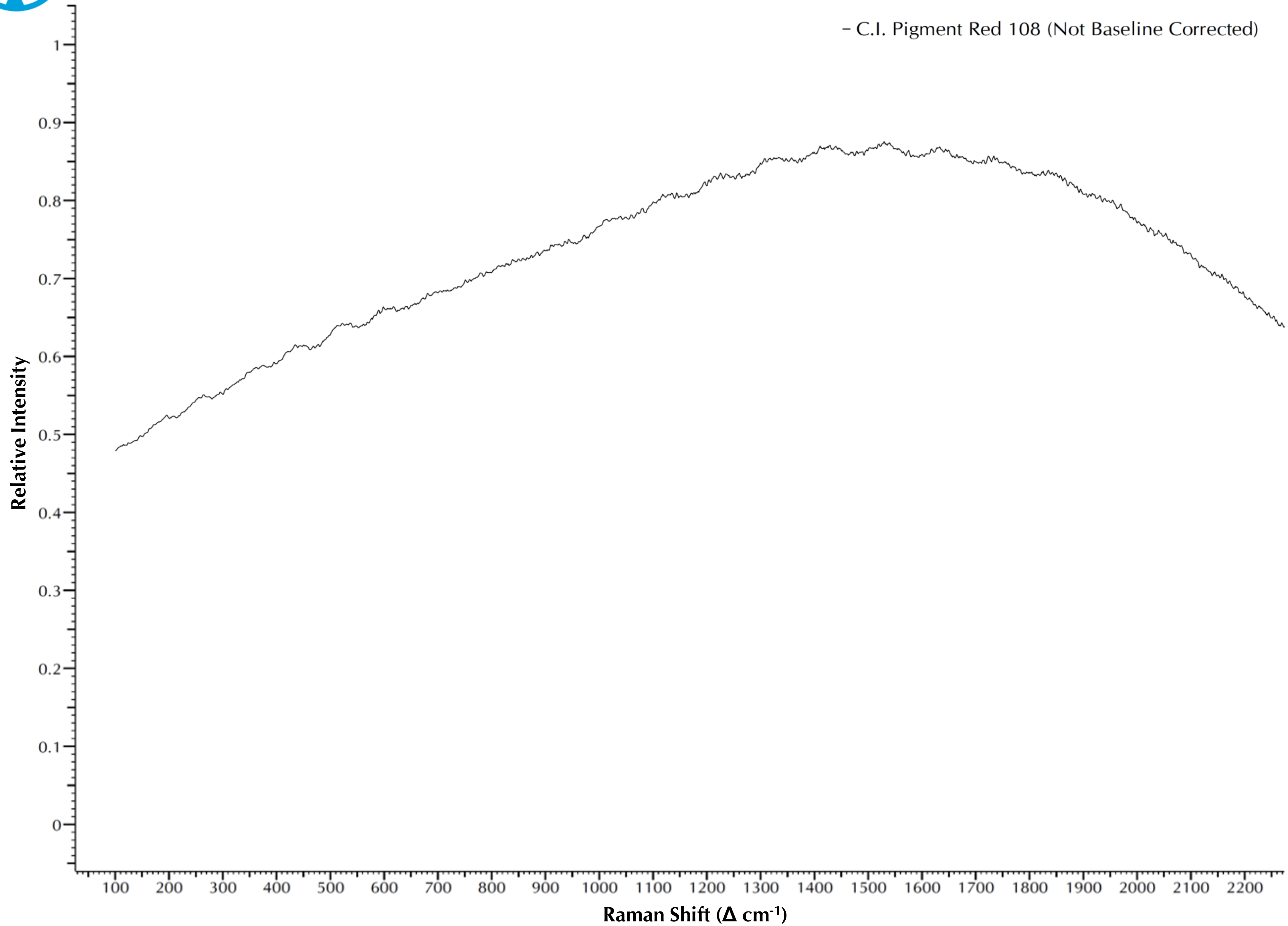
Sulfide – monosulfide/disulfide



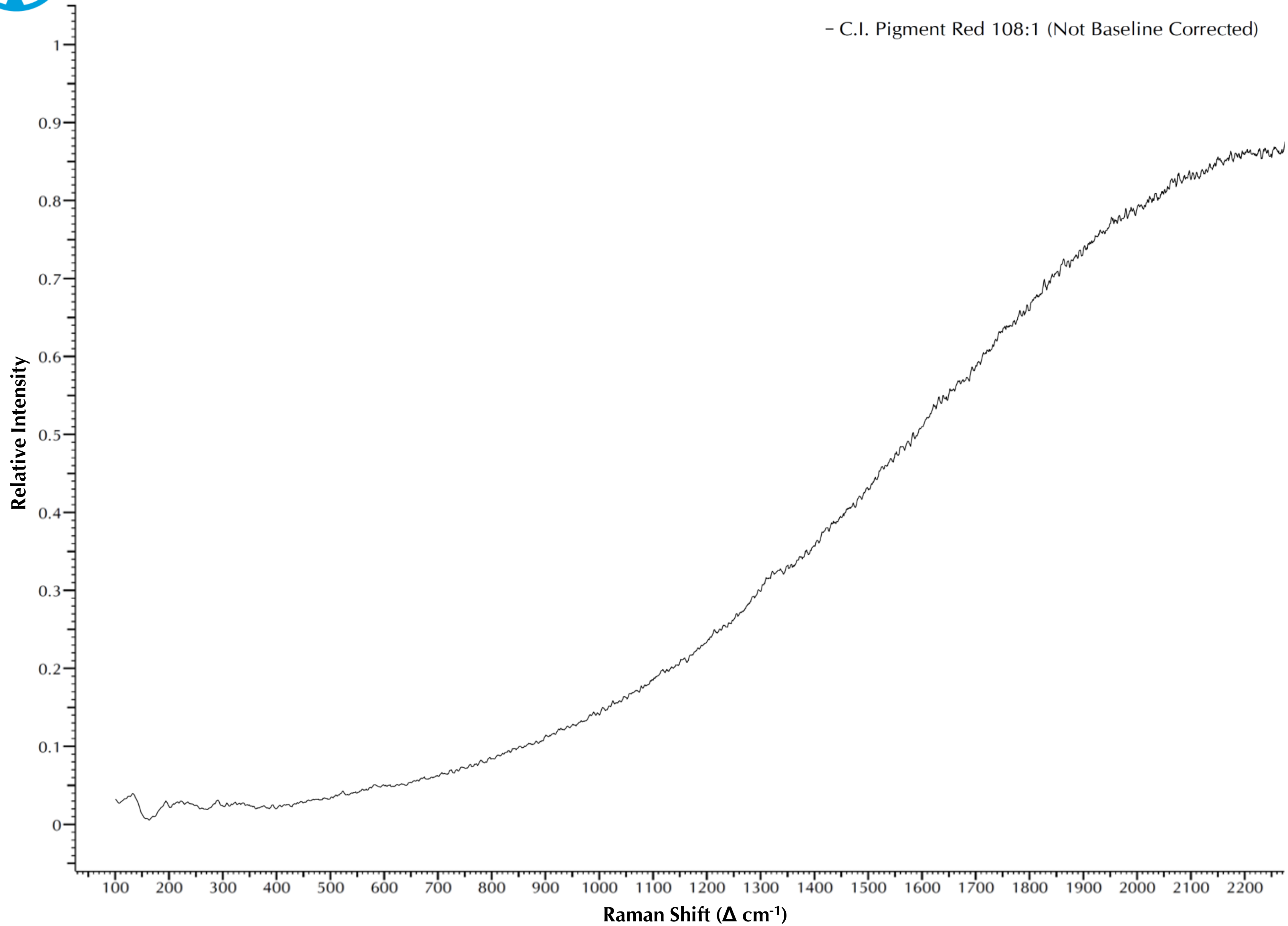
Sulfide – monosulfide/disulfide



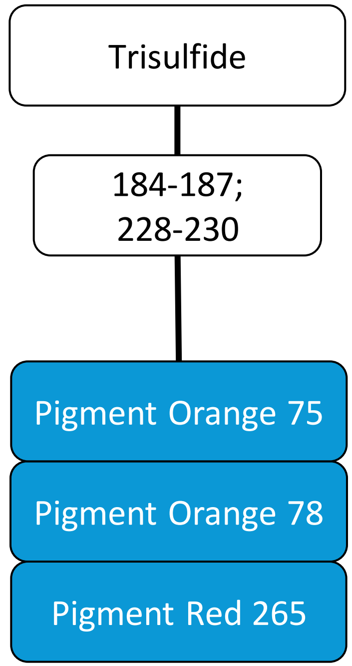
Sulfide – monosulfide/disulfide



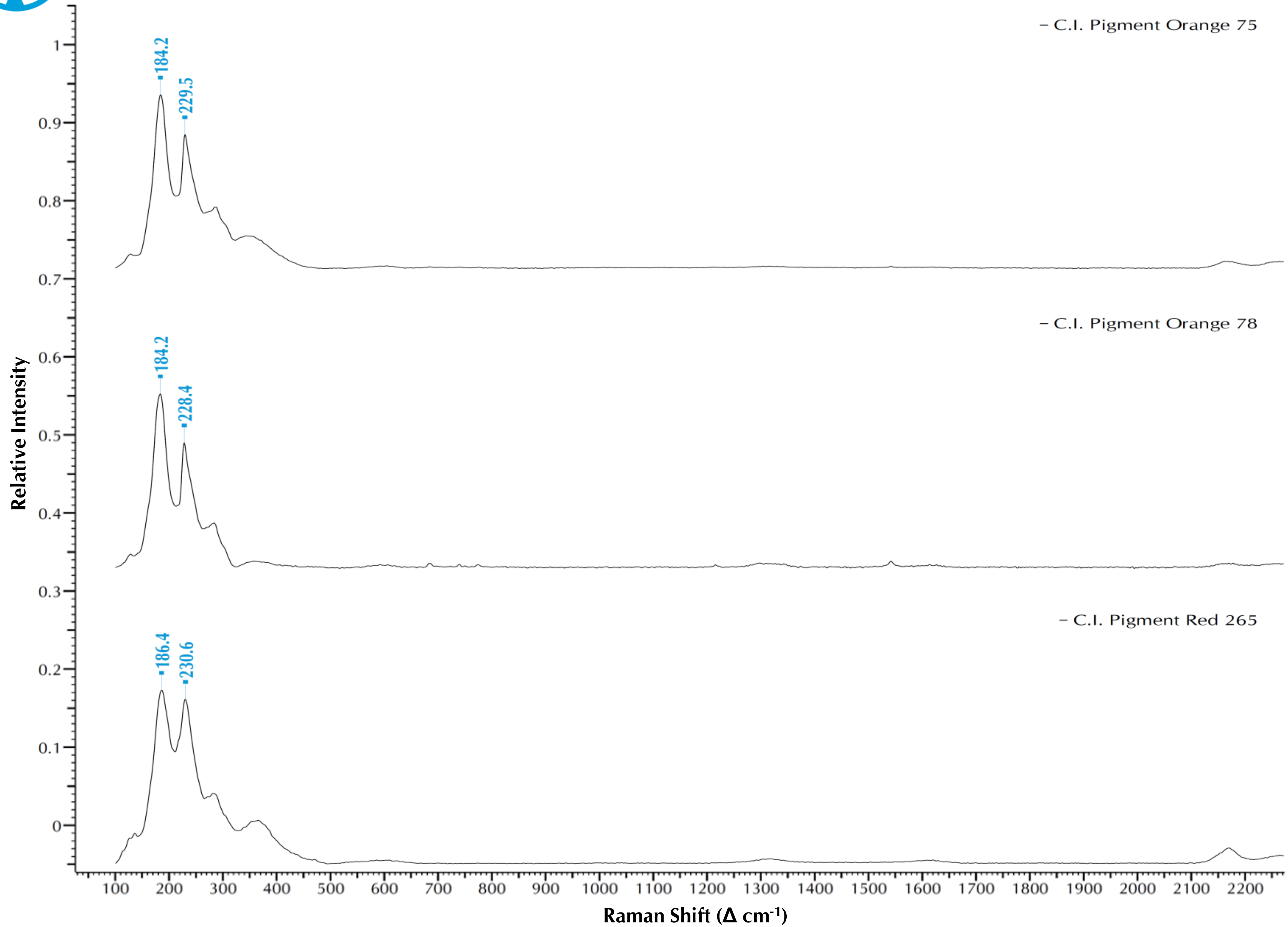
Sulfide – monosulfide/disulfide



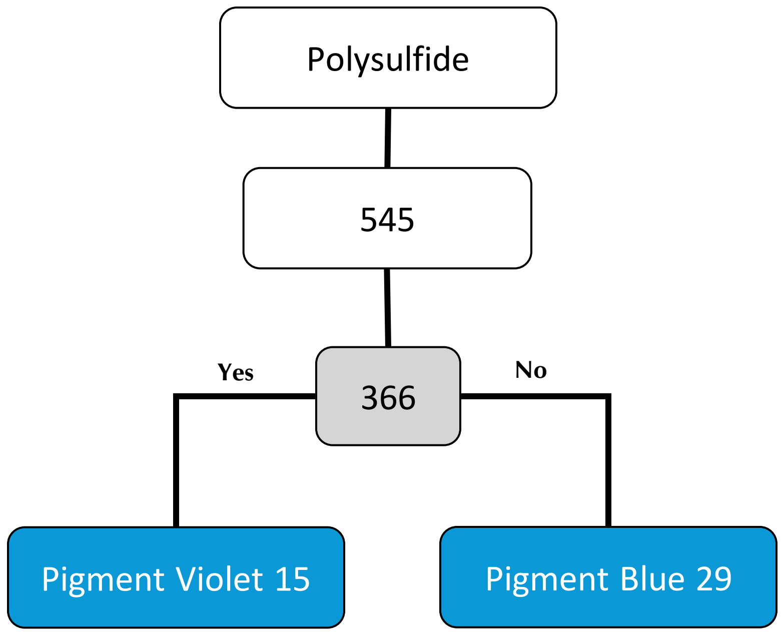
Sulfide - trisulfide



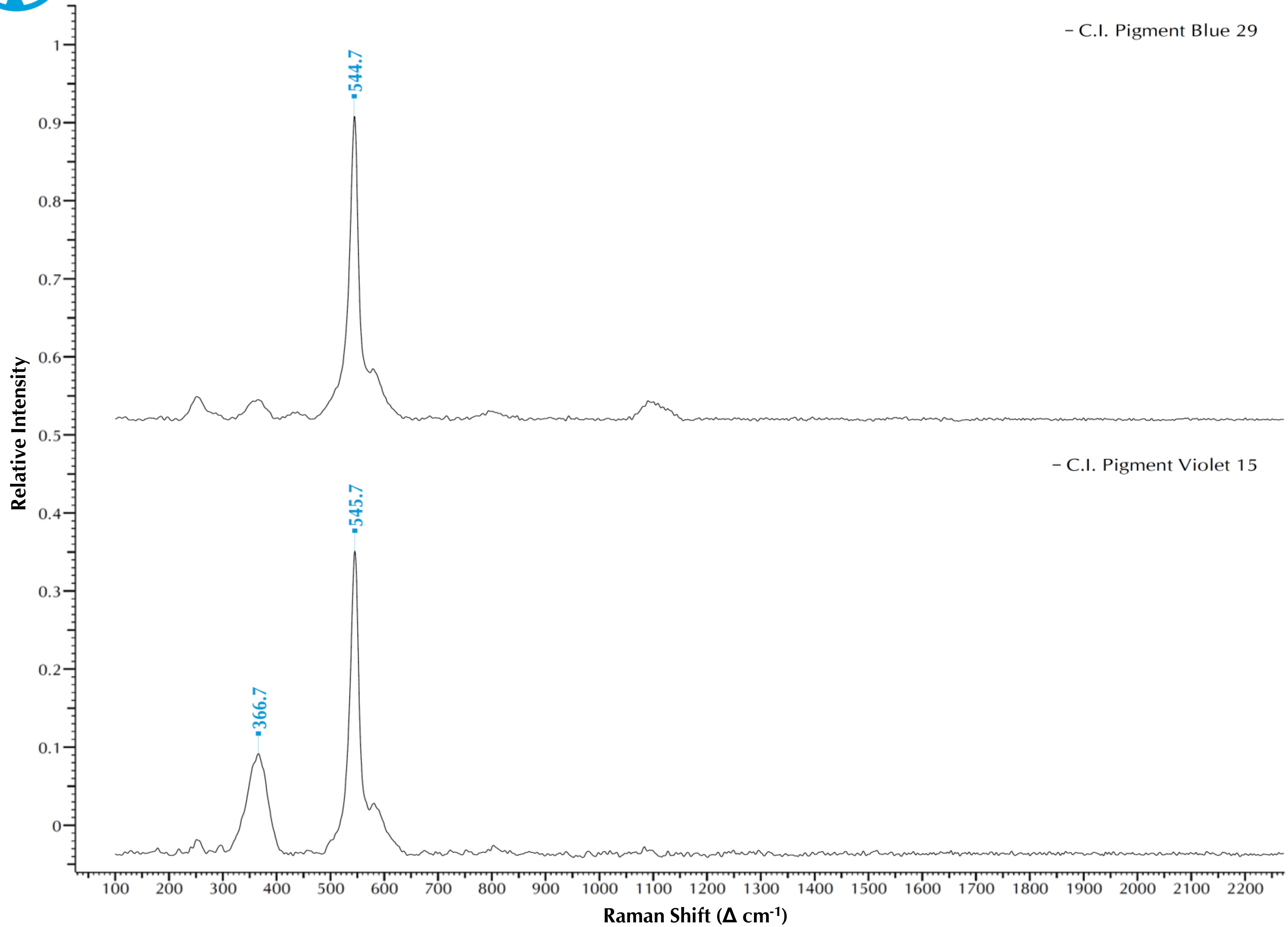
Sulfide - trisulfide



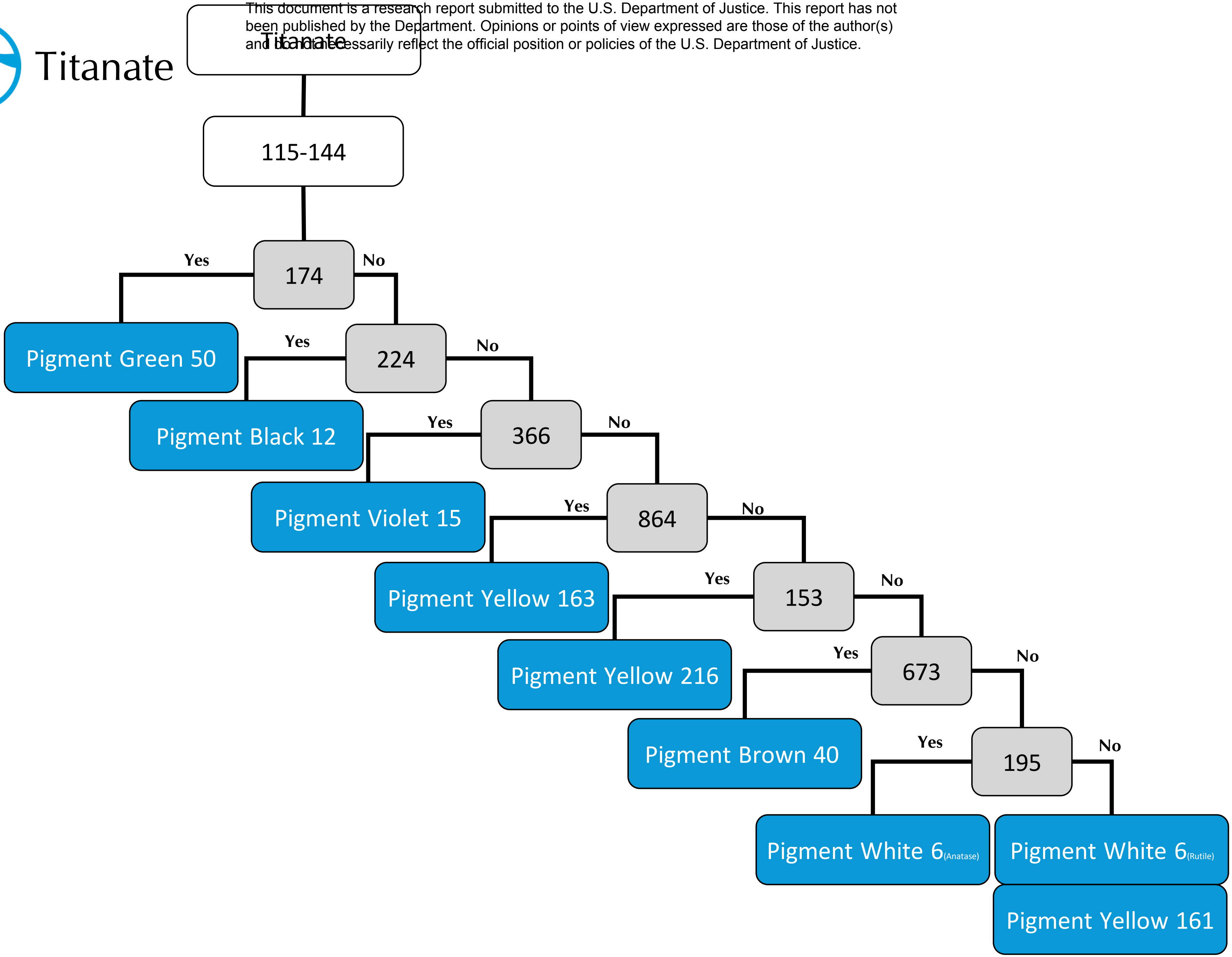
Sulfide - polysulfide



Sulfide - polysulfide



Titanate



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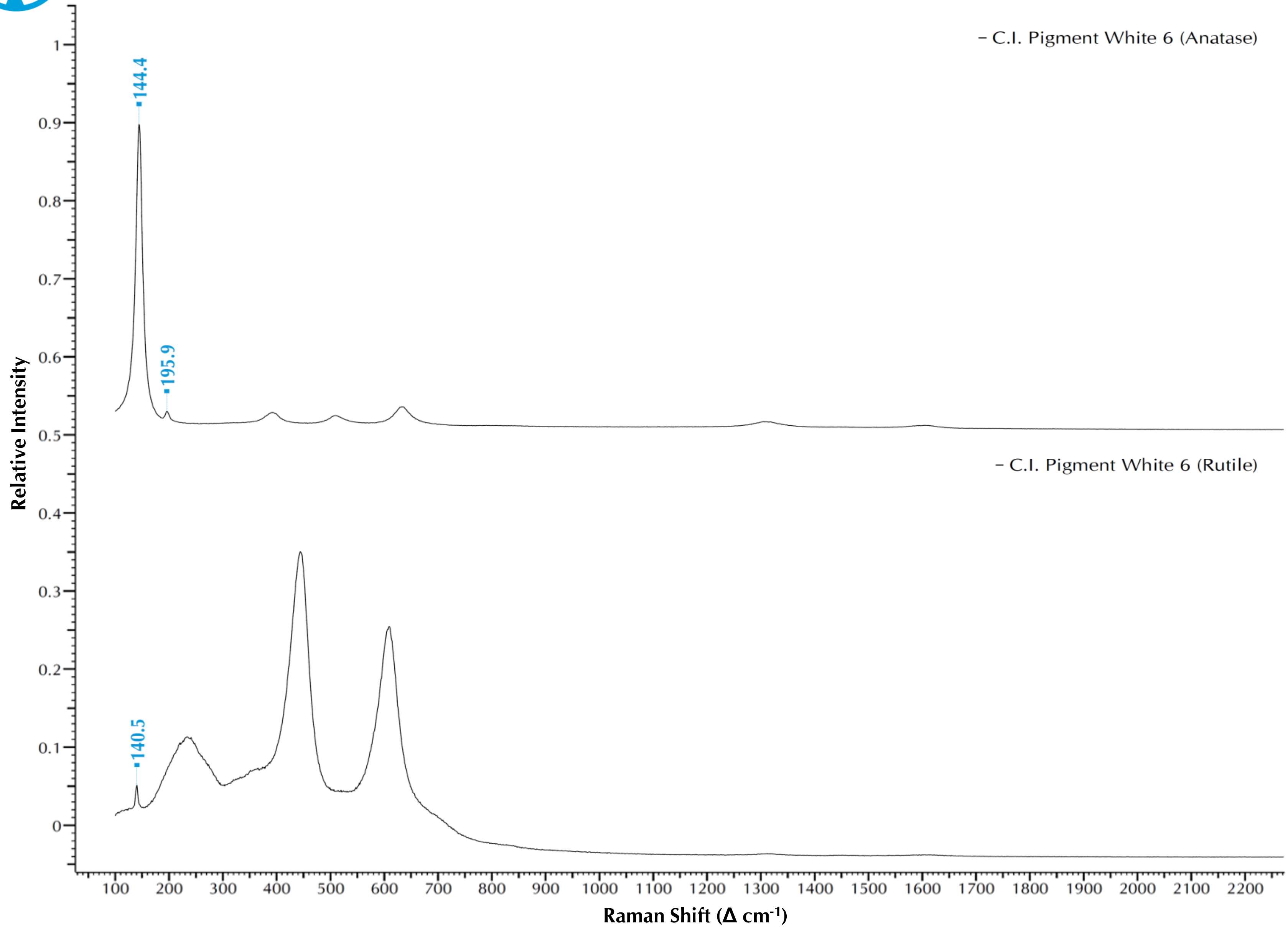
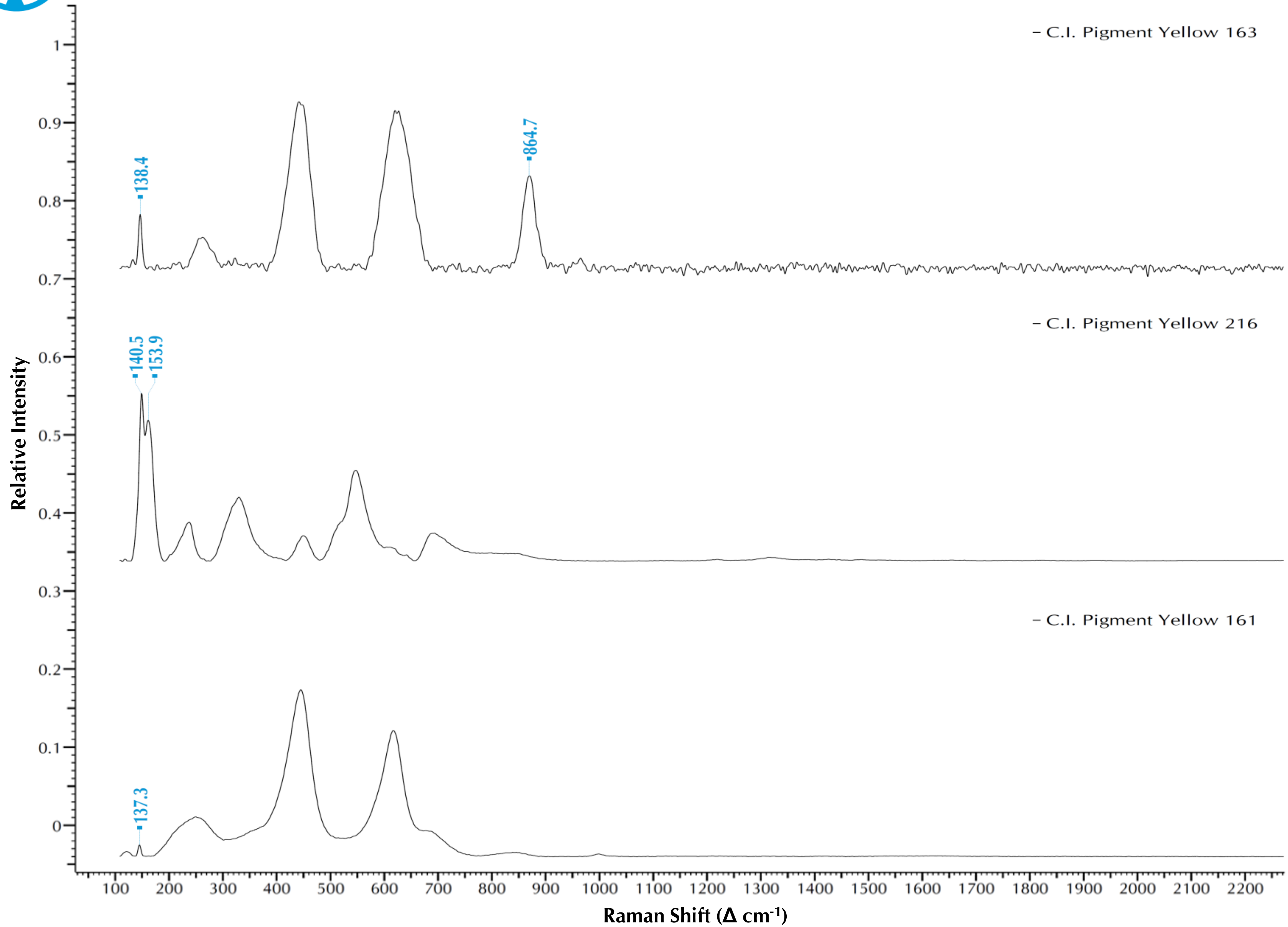
Titanate



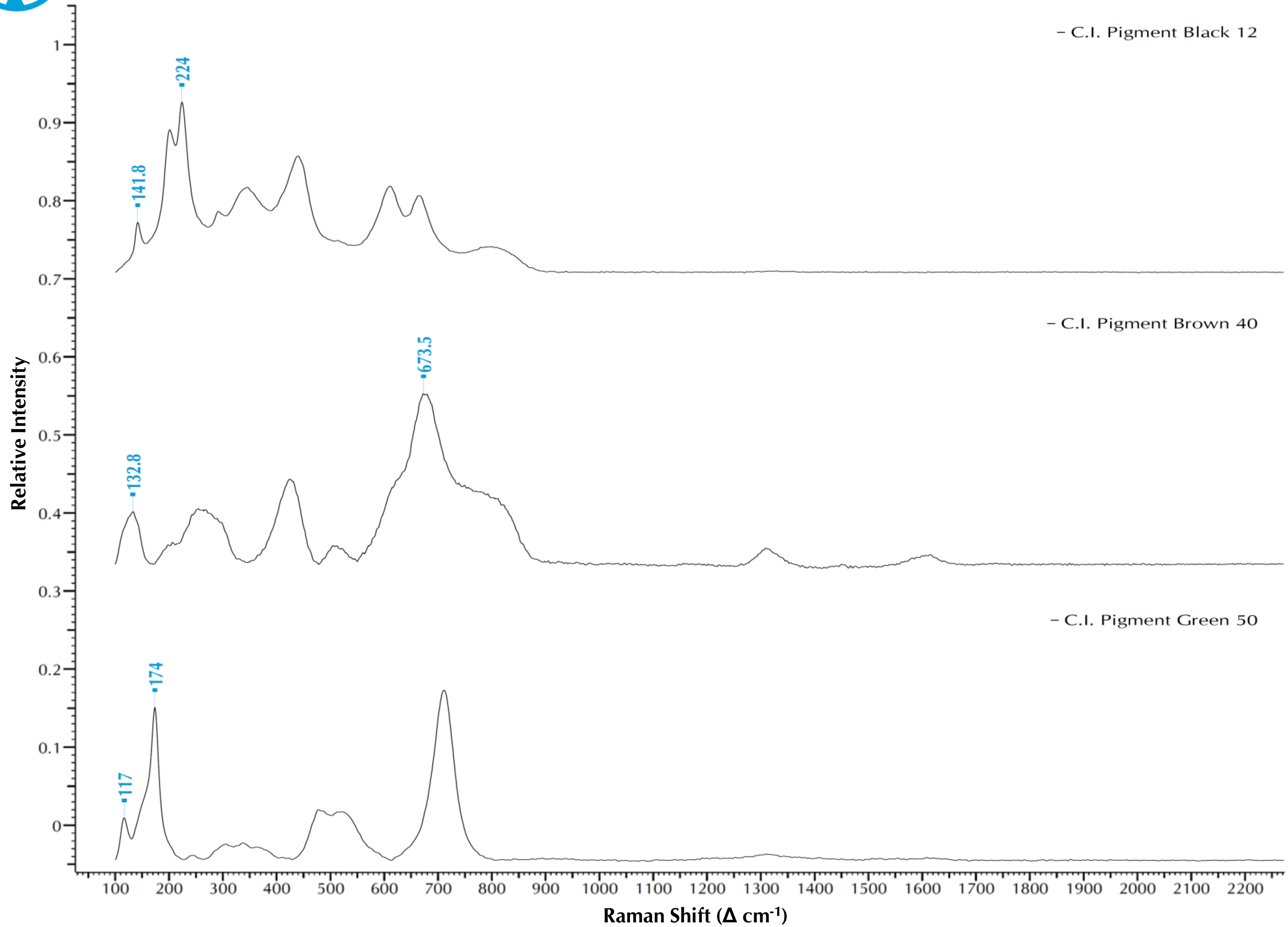
– C.I. Pigment White 6 (Anatase)
– C.I. Pigment White 6 (Rutile)
144.4
195.9
140.5
Relative Intensity
Raman Shift (Δ cm-1)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Titanate



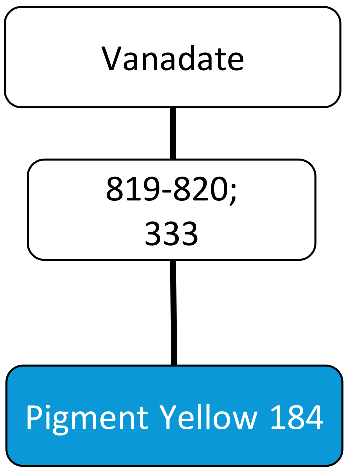
– C.I. Pigment Yellow 163
– C.I. Pigment Yellow 216
– C.I. Pigment Yellow 161
138.4
864.7
140.5
153.9
137.3
Relative Intensity
Raman Shift (Δ cm⁻¹)

Titanate

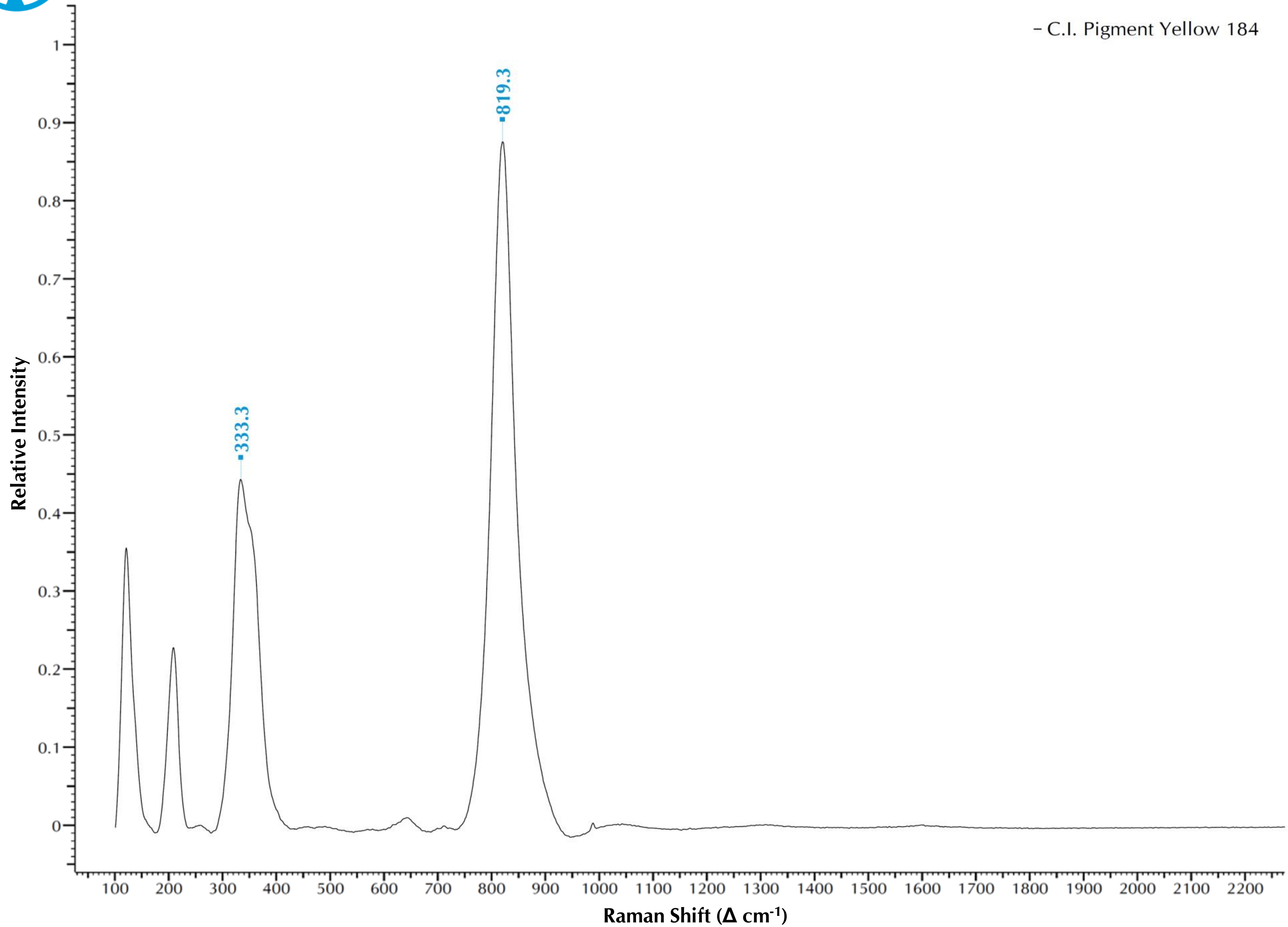


C.I. Pigment Black 12
C.I. Pigment Brown 40
C.I. Pigment Green 50
224
141.8
673.5
132.8
174
117
Relative Intensity
Raman Shift (Δ cm-1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Vanadate

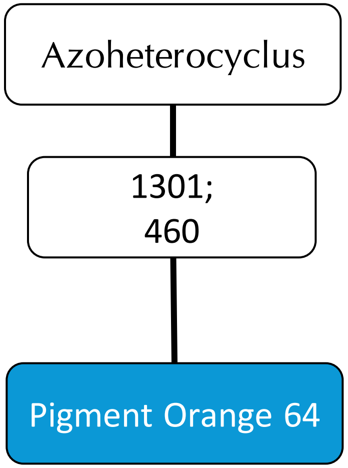


Vanadate

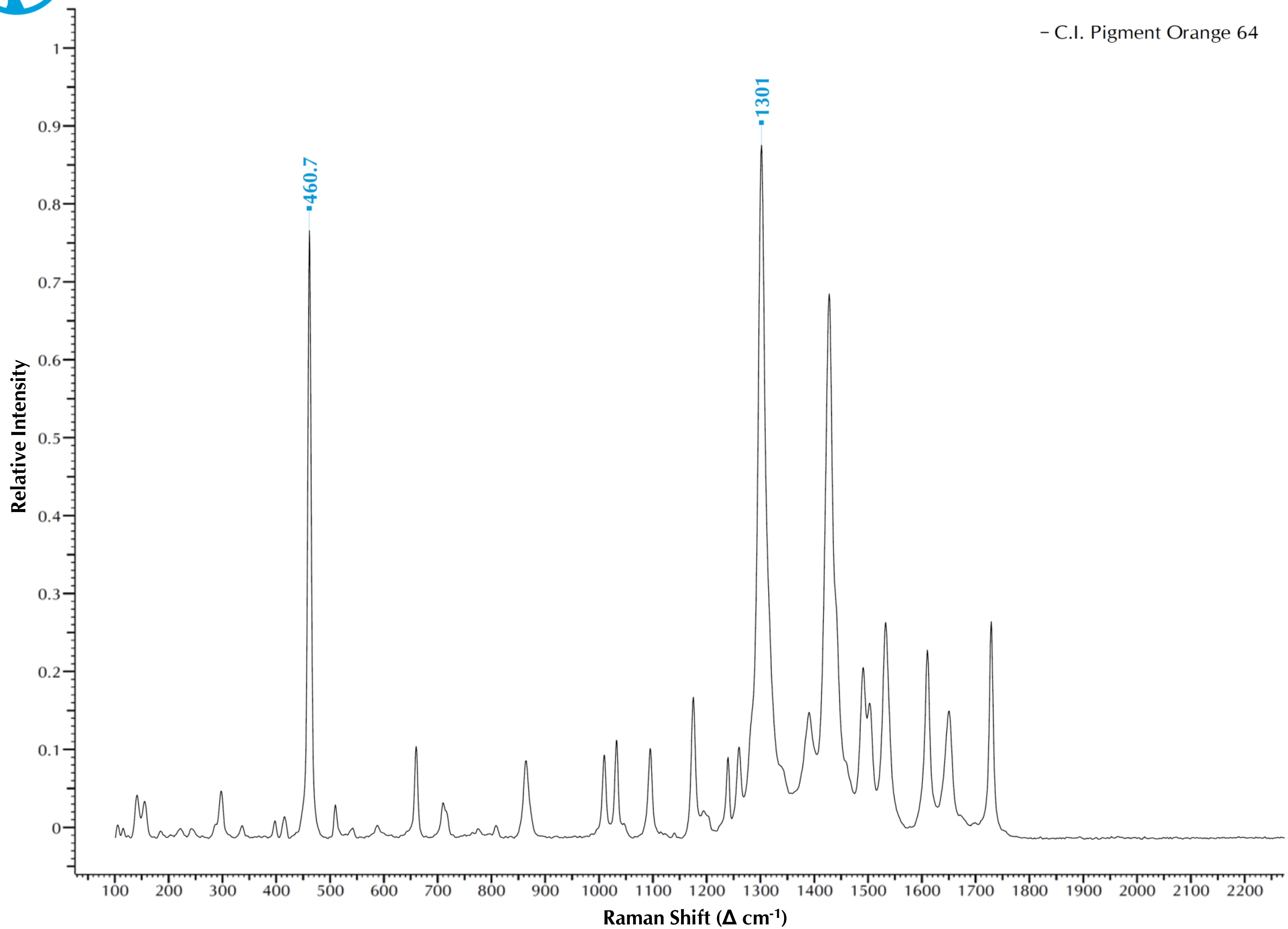


- C.I. Pigment Yellow 184
819.3
333.3
Relative Intensity
Raman Shift (Δ cm-1)

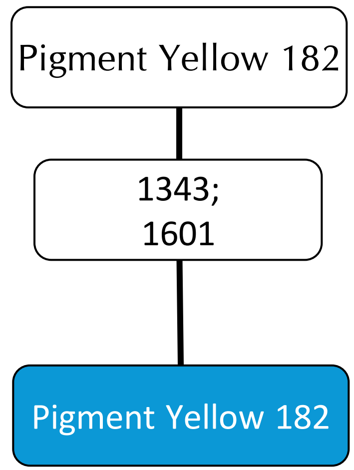
Azoheterocyclus



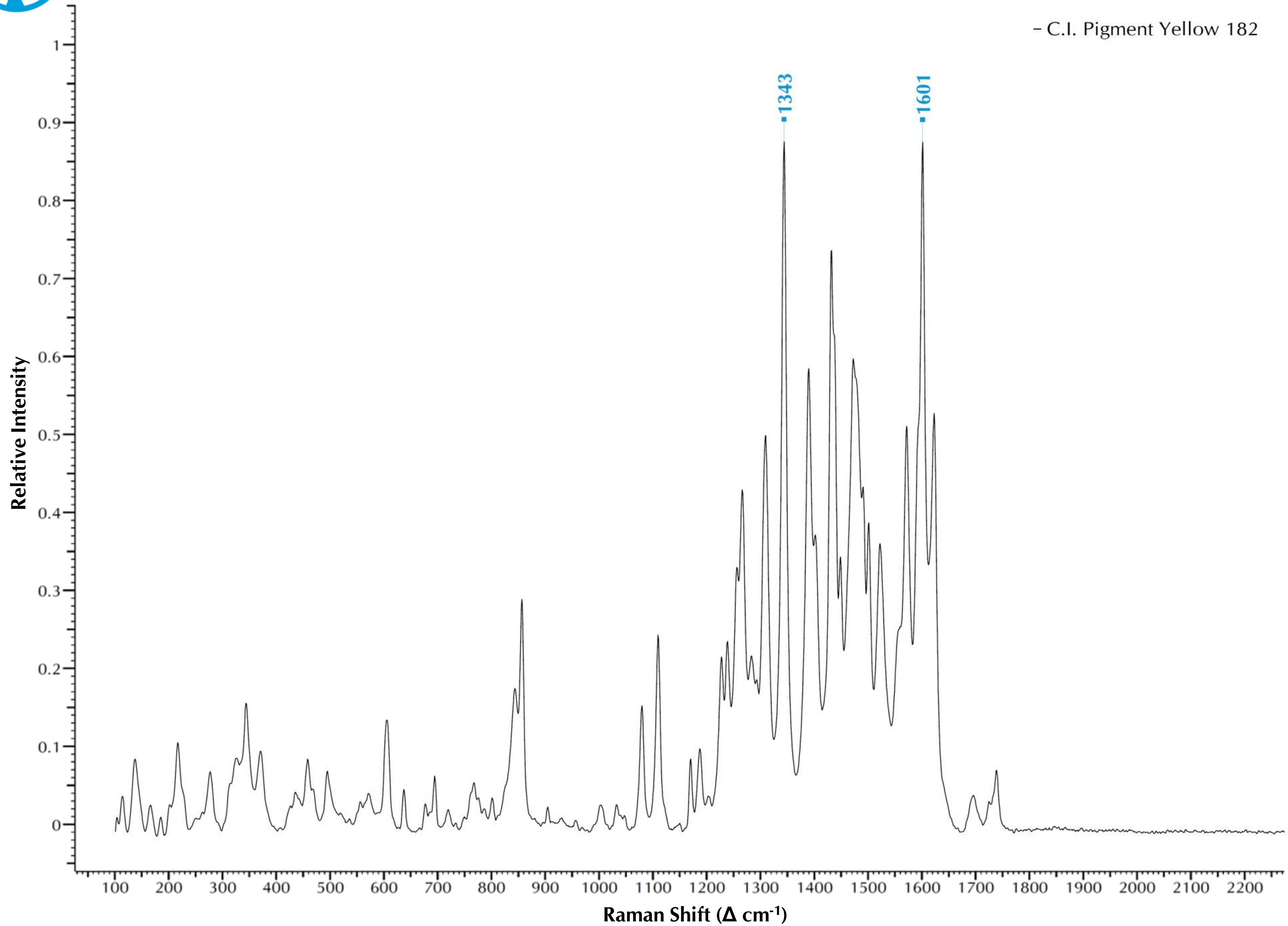
Azoheterocyclus



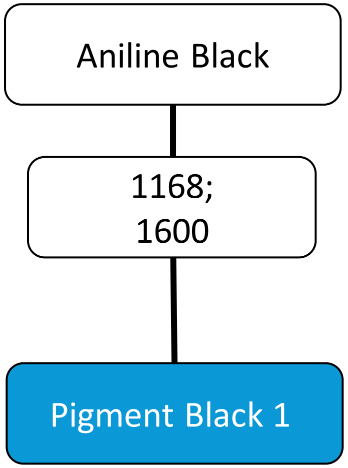
Pigment Yellow 182



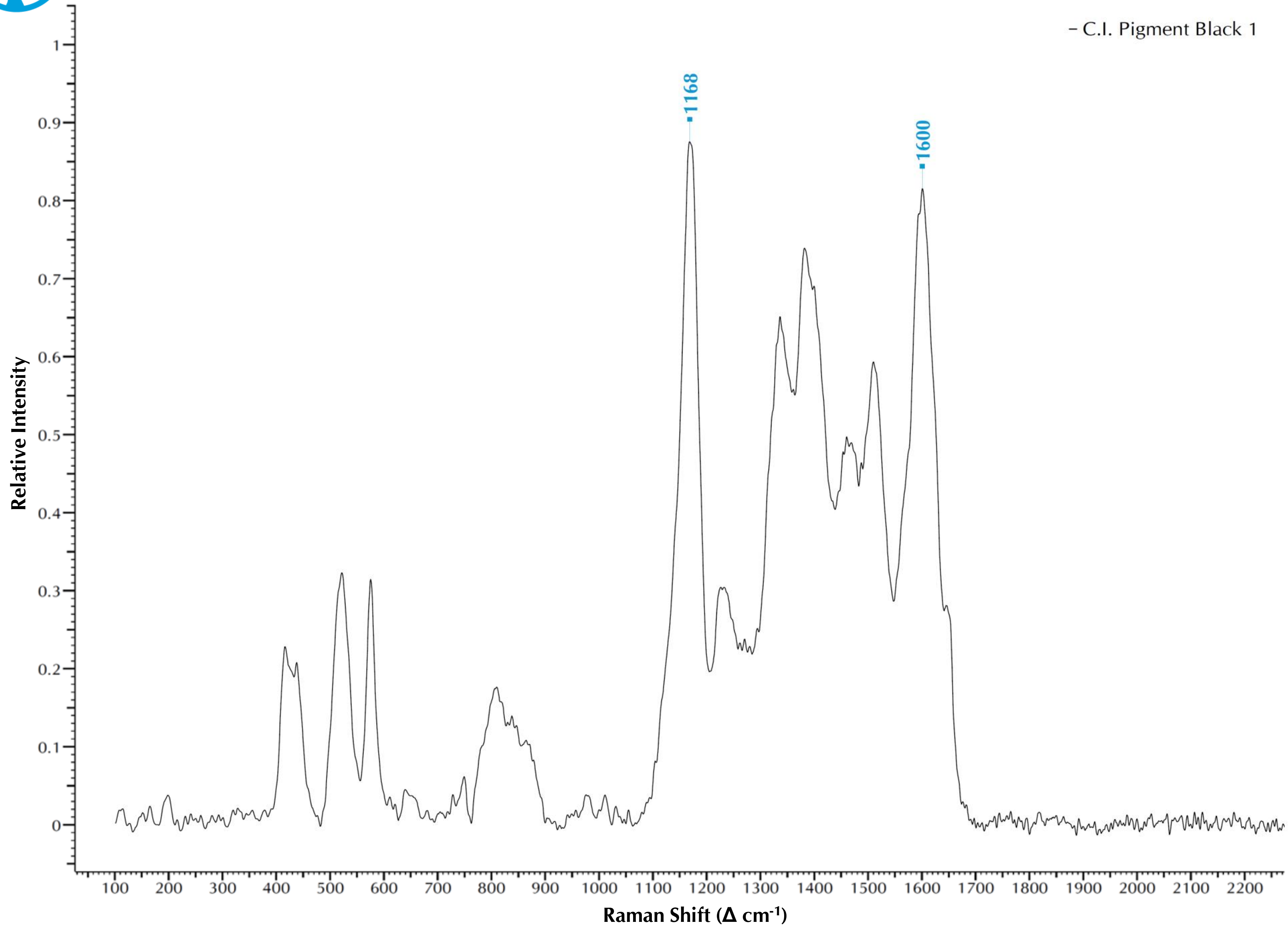
Pigment Yellow 182



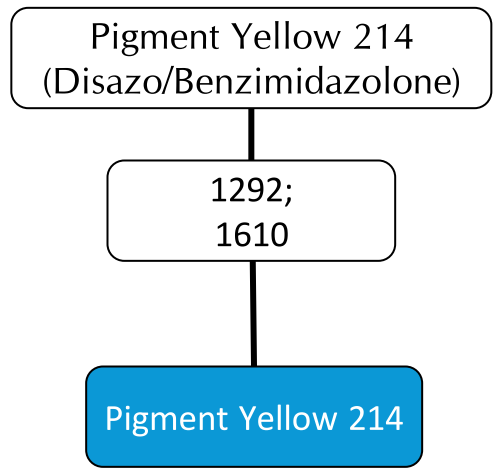
Aniline Black



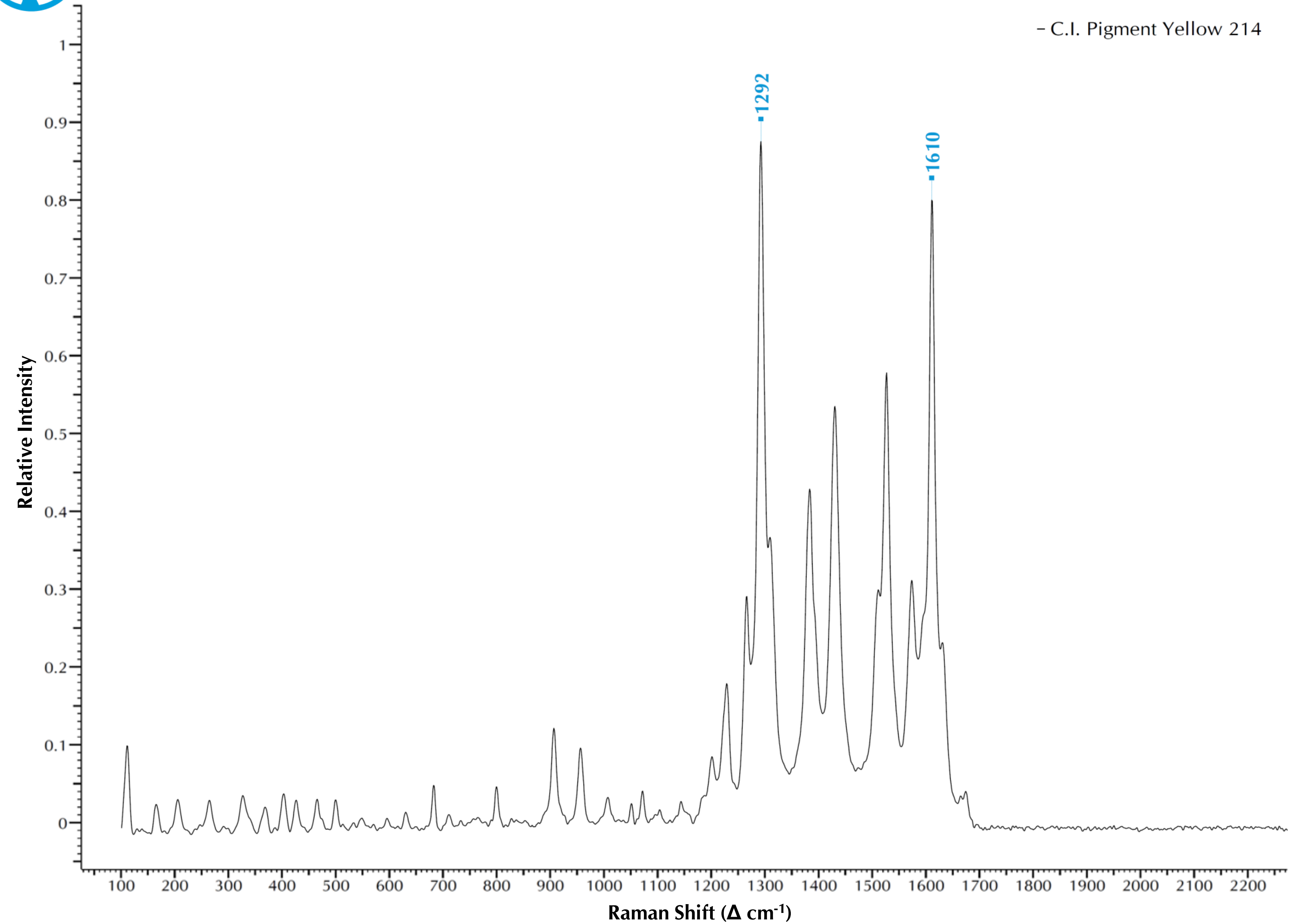
Aniline Black



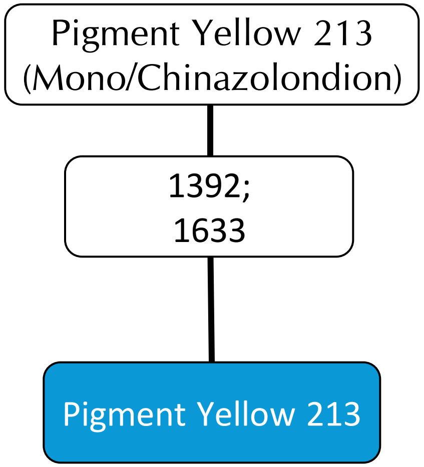
Pigment Yellow 214 (Disazo/Benzimidazolone)



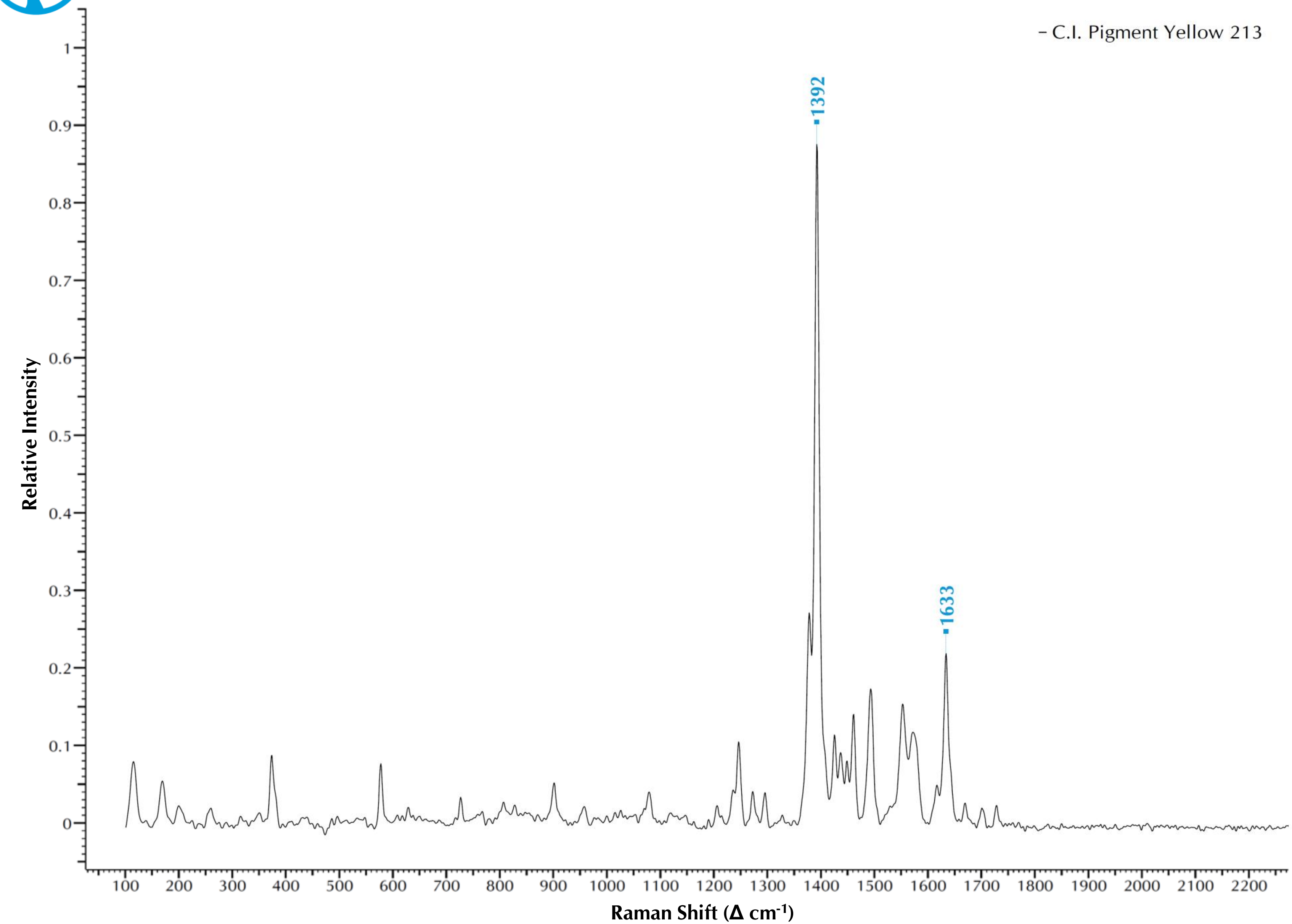
Pigment Yellow 214 (Disazo/Benzimidazolone)



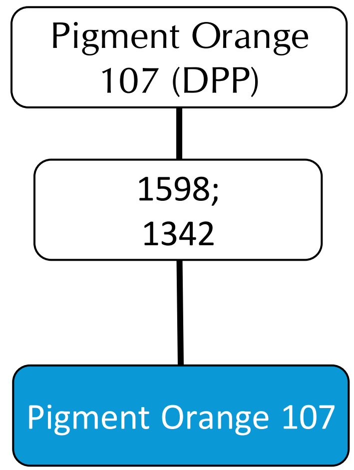
Pigment Yellow 213 (Mono/Chinazolondion)



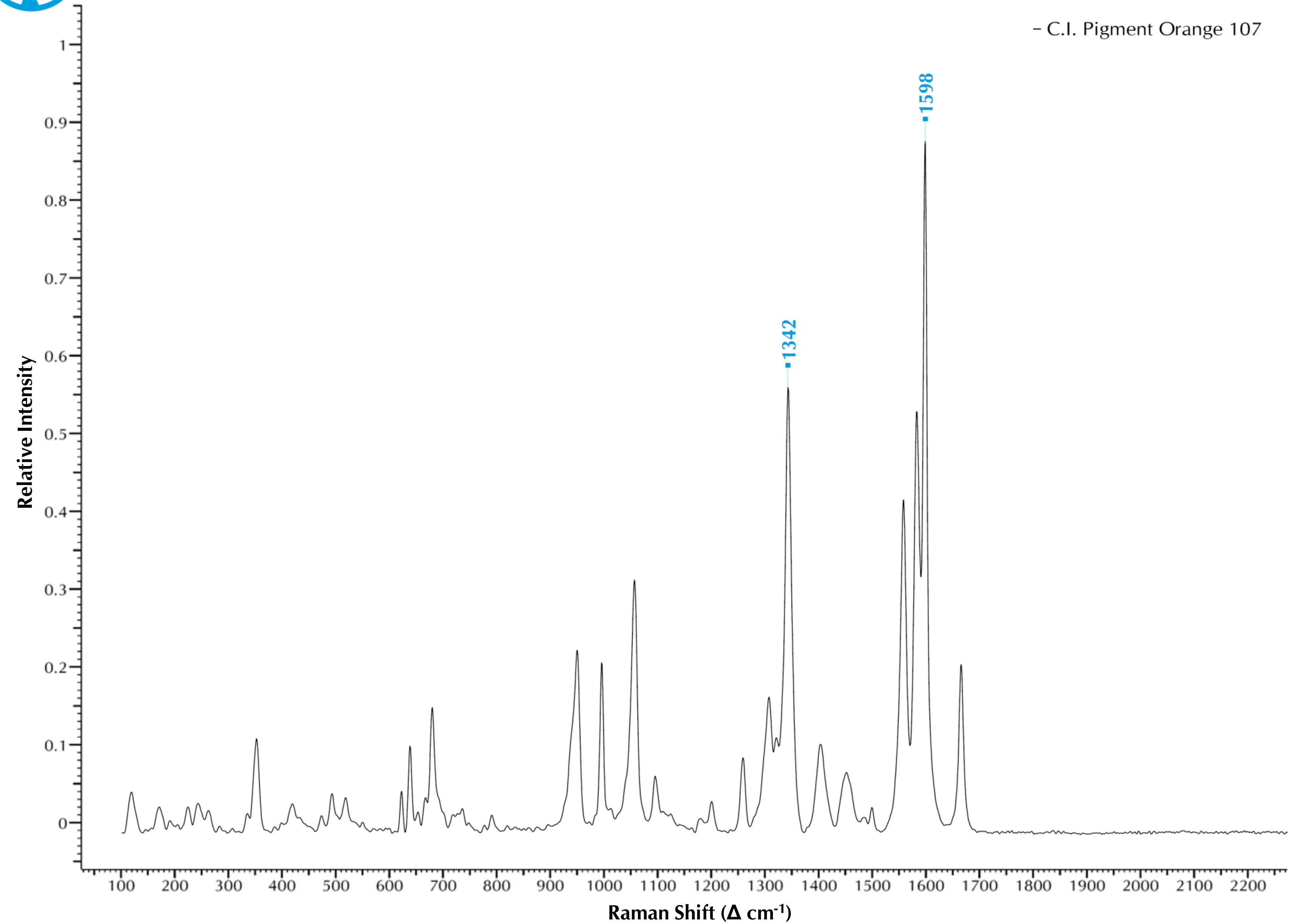
Pigment Yellow 213 (Mono/Chinazolondion)



Pigment Orange 107 (DPP)



Pigment Orange 107 (DPP)



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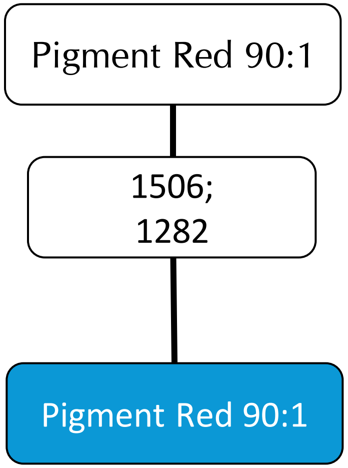
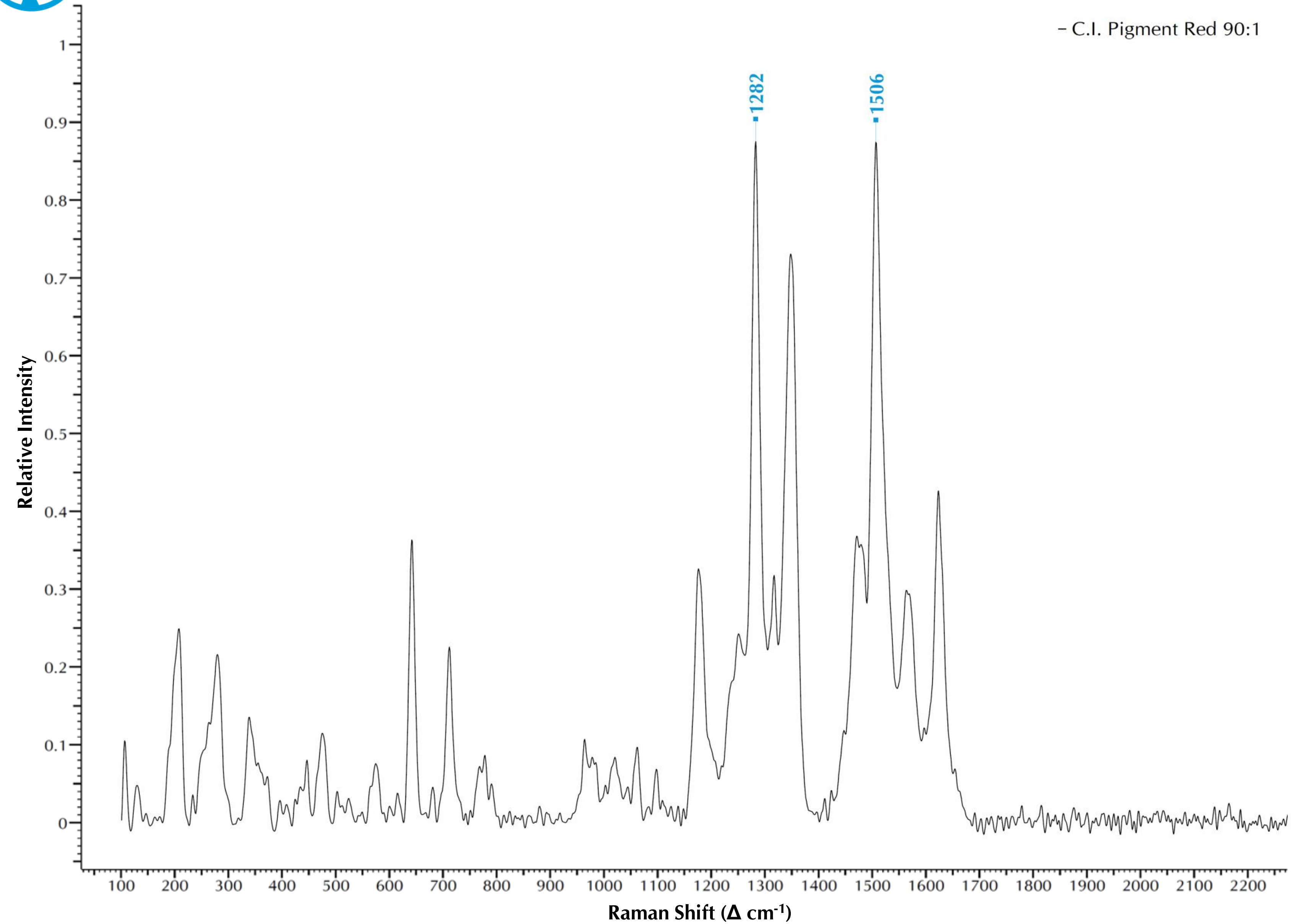
Pigment Red 90:1

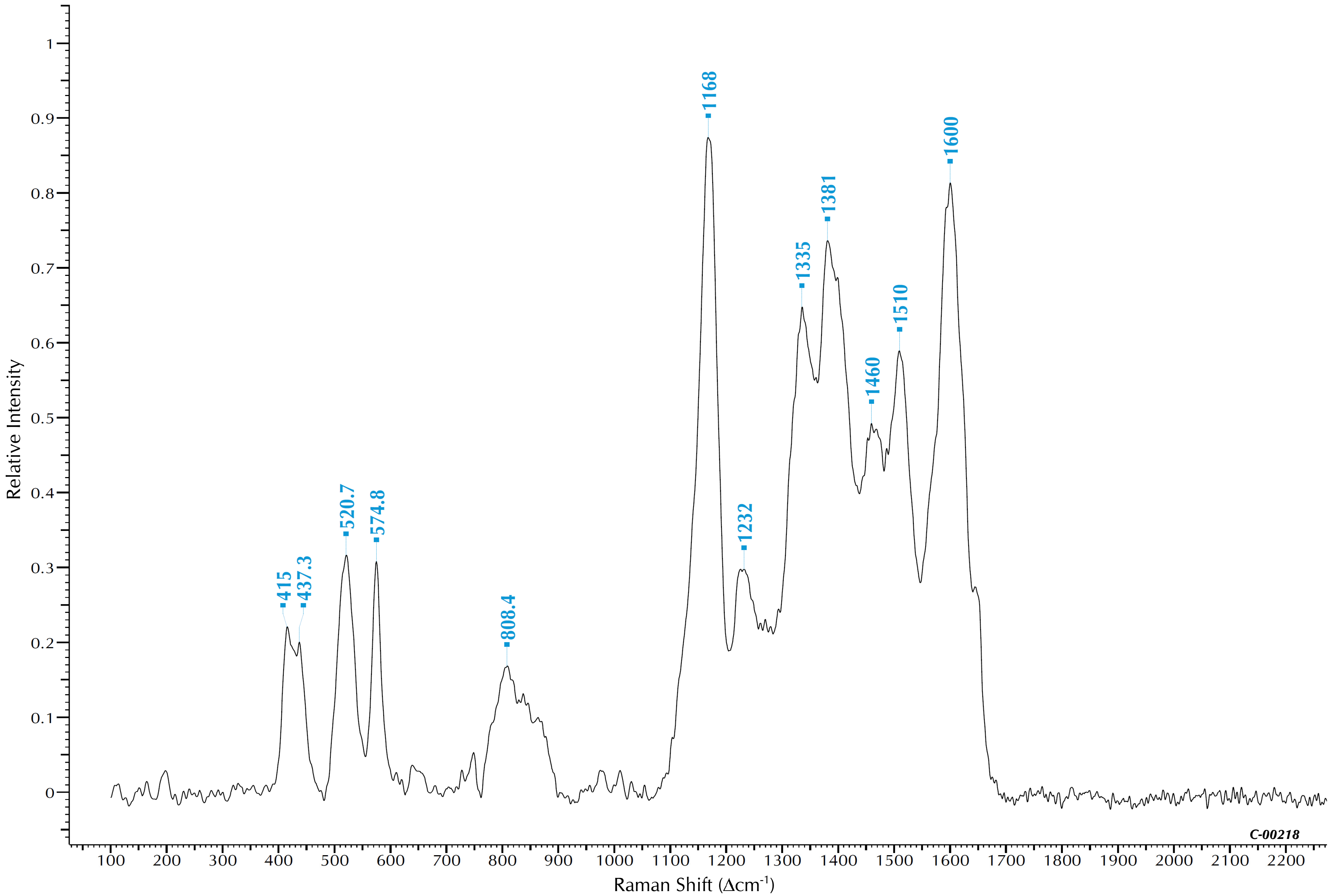


Pigment Red 90:1



APPENDIX D – PIGMENT CLASSIFICATION SCHEME

C.I. Pigment Black 1

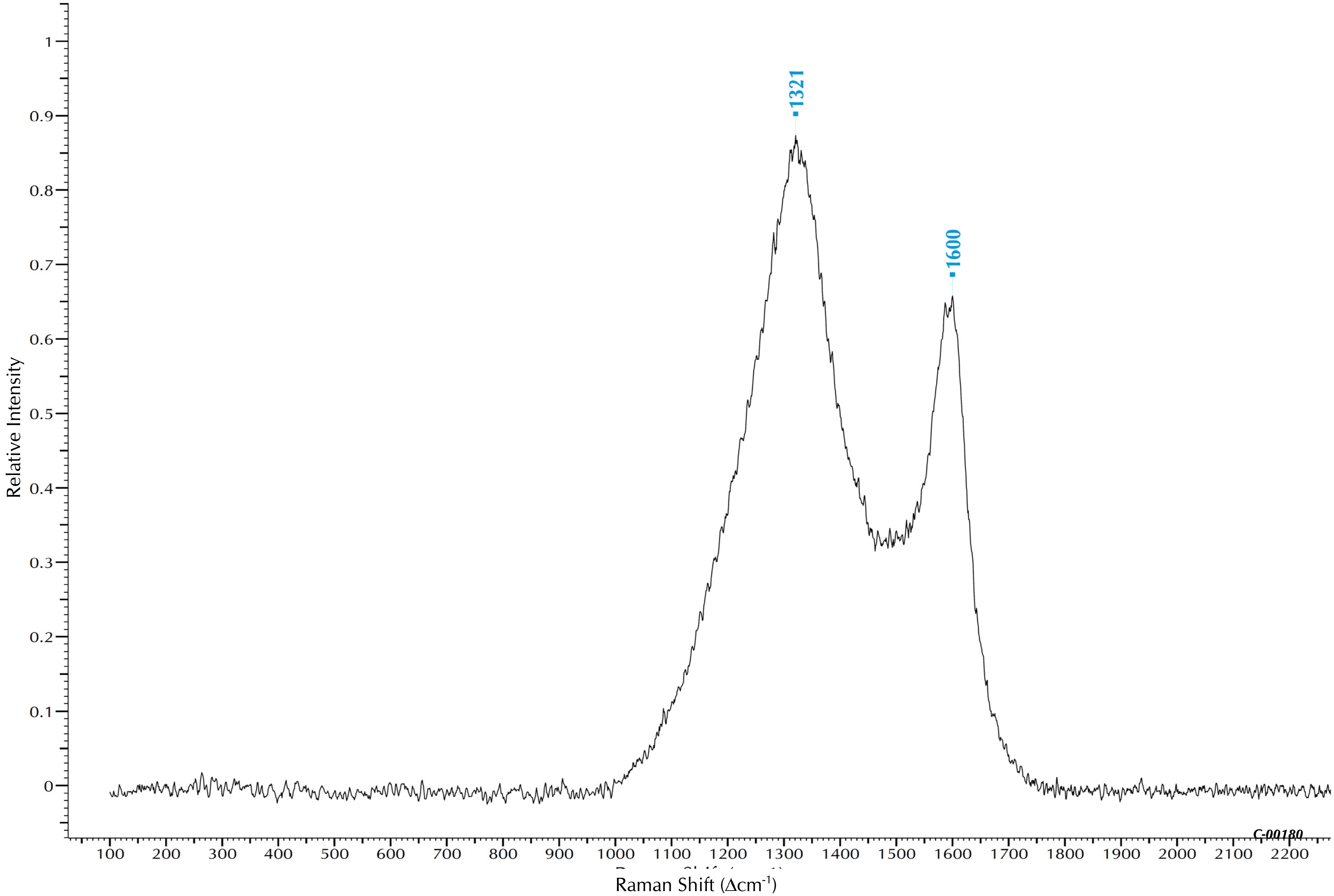


Chemical Category: Organic - Other
Constitution Number: 50440

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

C.I. Pigment Black 7



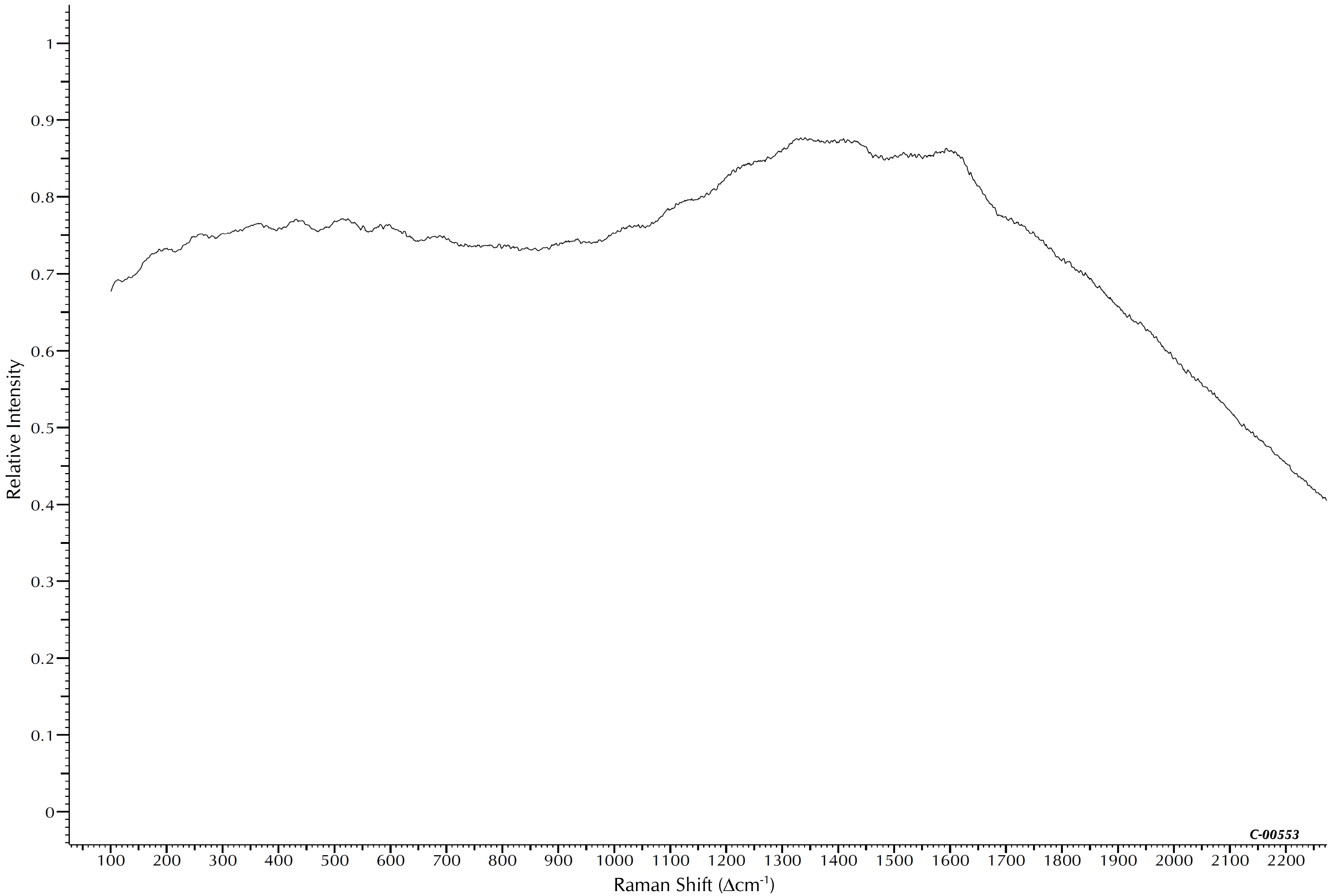
Chemical Category: Inorganic - Carbon
Constitution Number: 77266

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Black 8



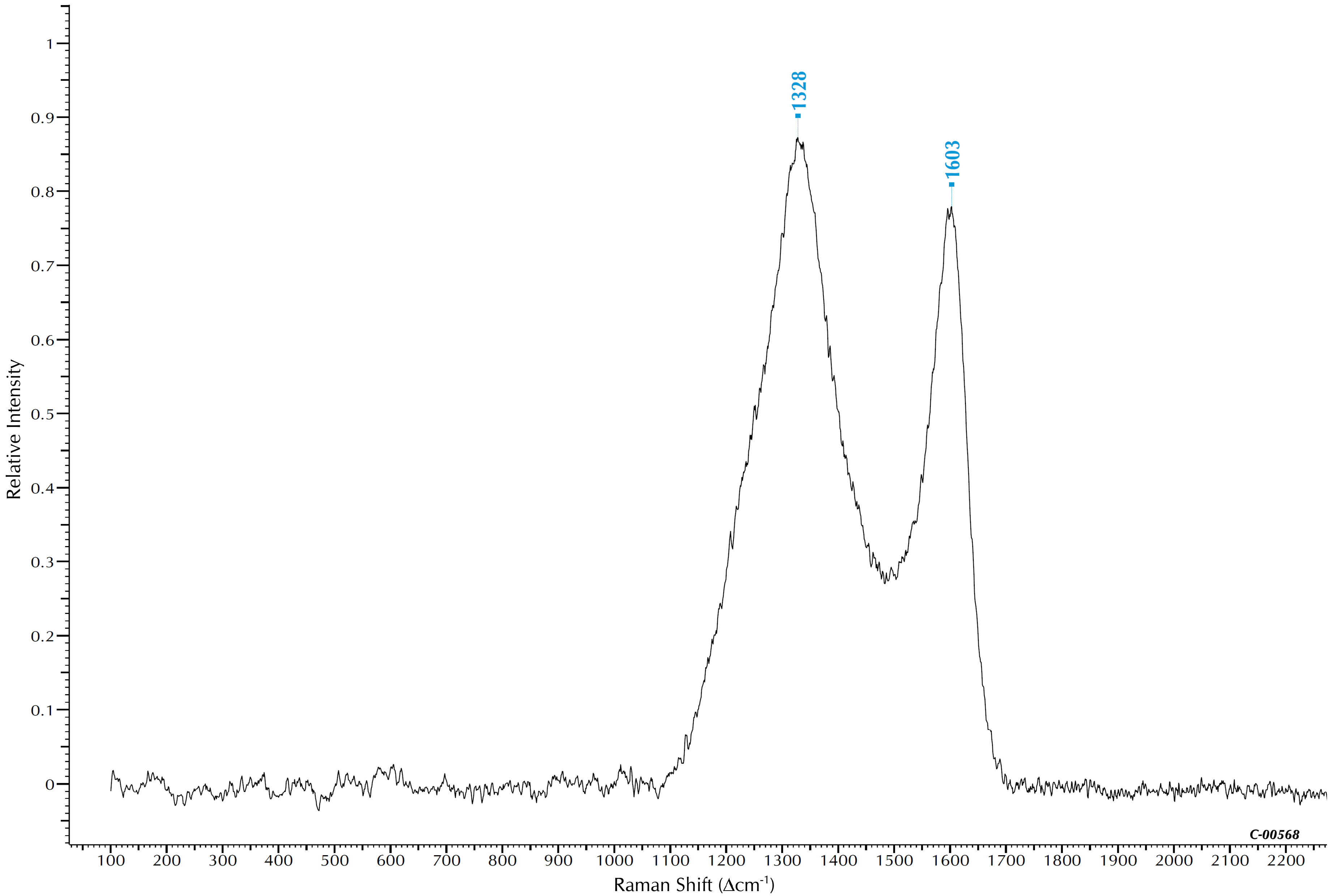
Chemical Category: Inorganic - Carbon
Constitution Number: 77268

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 5

Microtrace LLC

C.I. Pigment Black 9



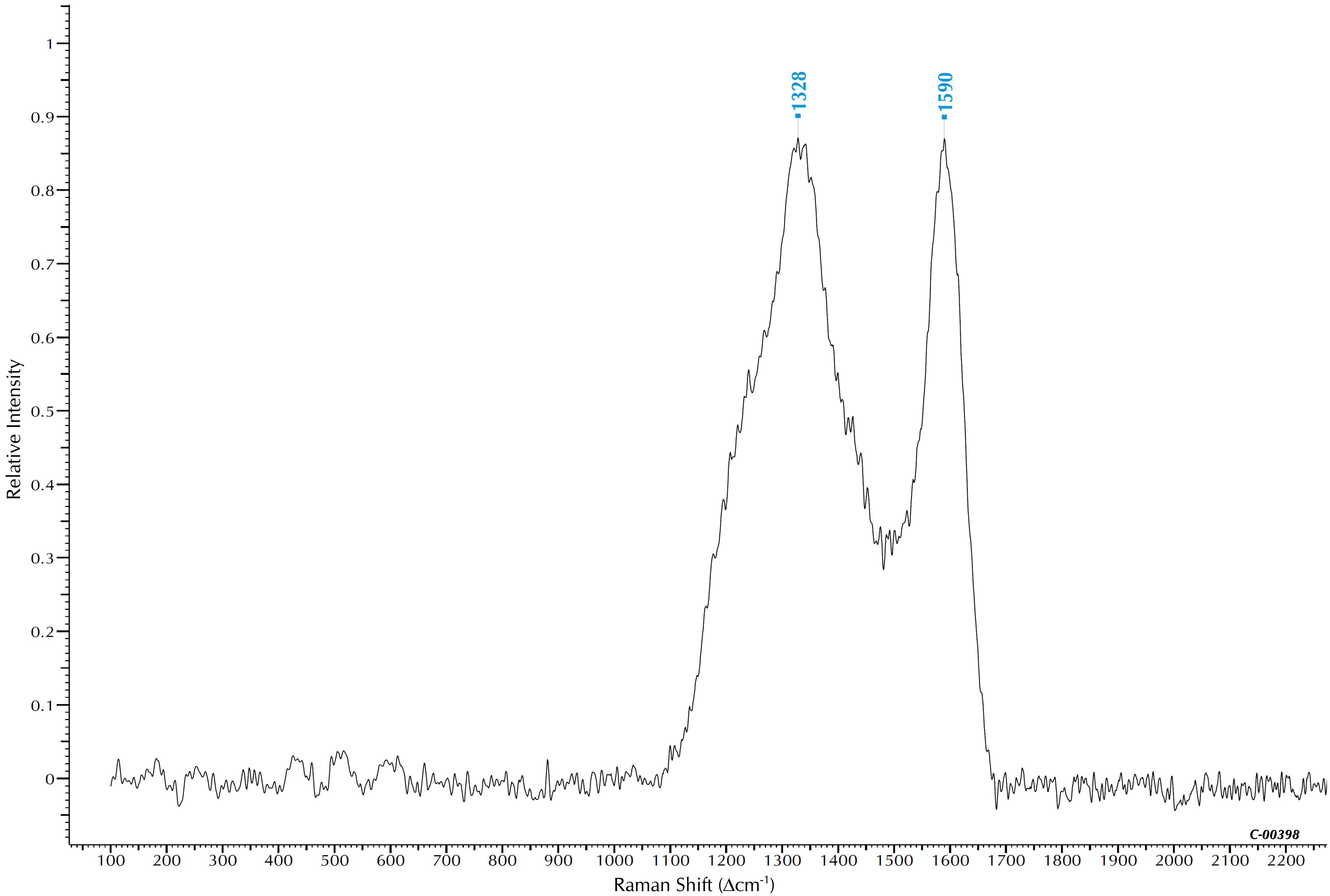
Chemical Category: Inorganic - Carbon
Constitution Number: 77267

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 4

Microtrace LLC

C.I. Pigment Black 10



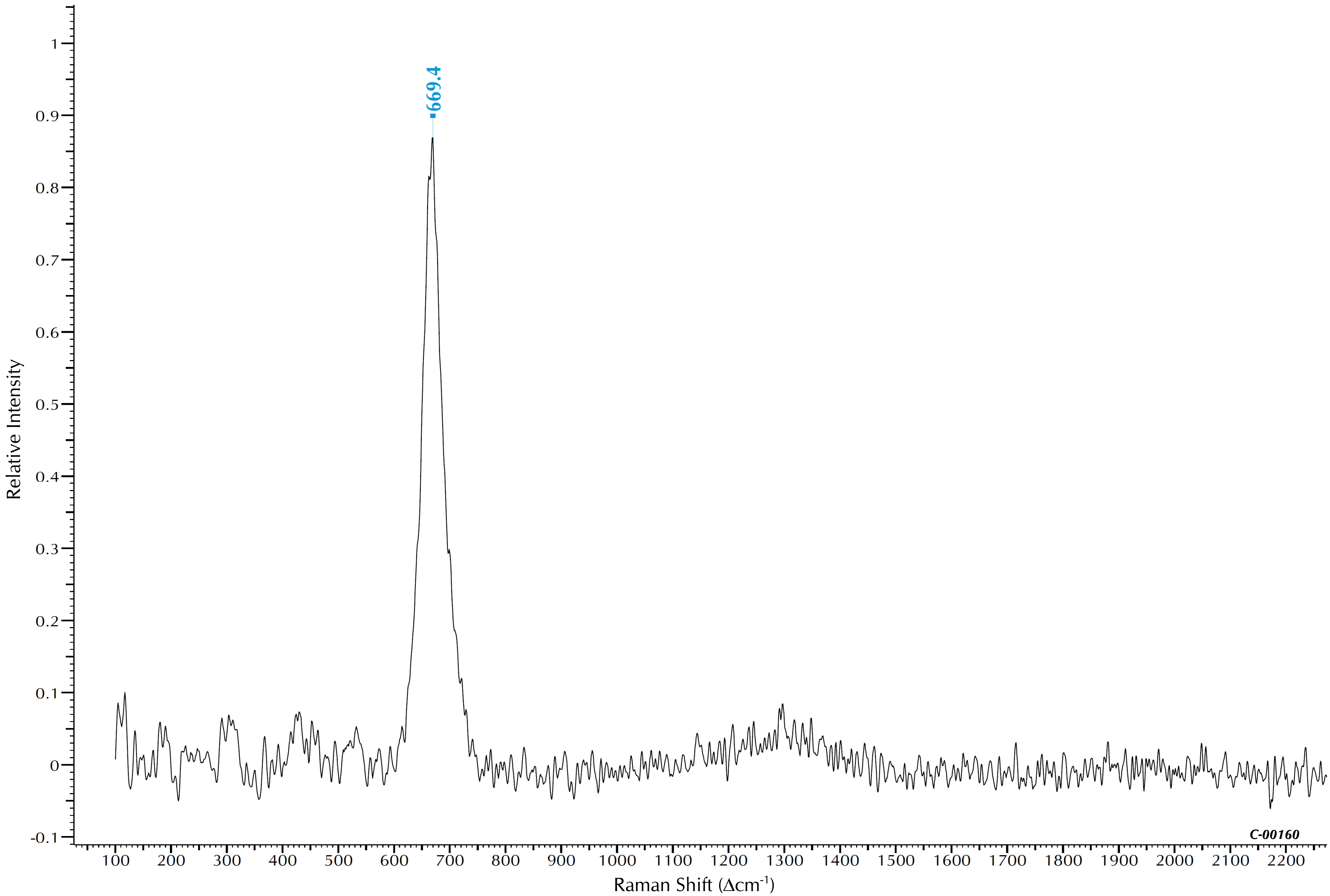
Chemical Category: Inorganic - Carbon
Constitution Number: 77265

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 4

Microtrace LLC

C.I. Pigment Black 11



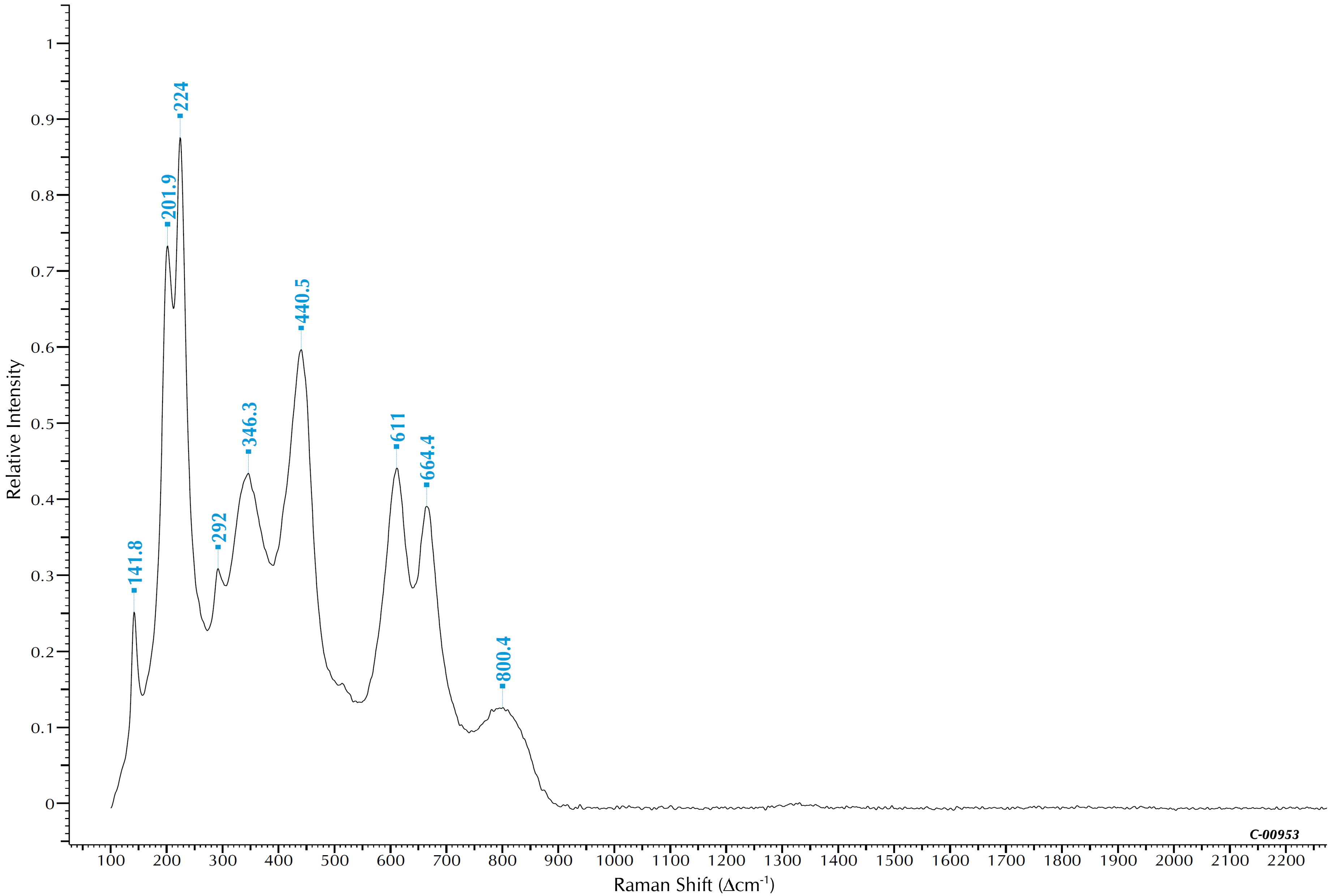
Chemical Category: Inorganic - Oxide
Constitution Number: 77499

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Black 12



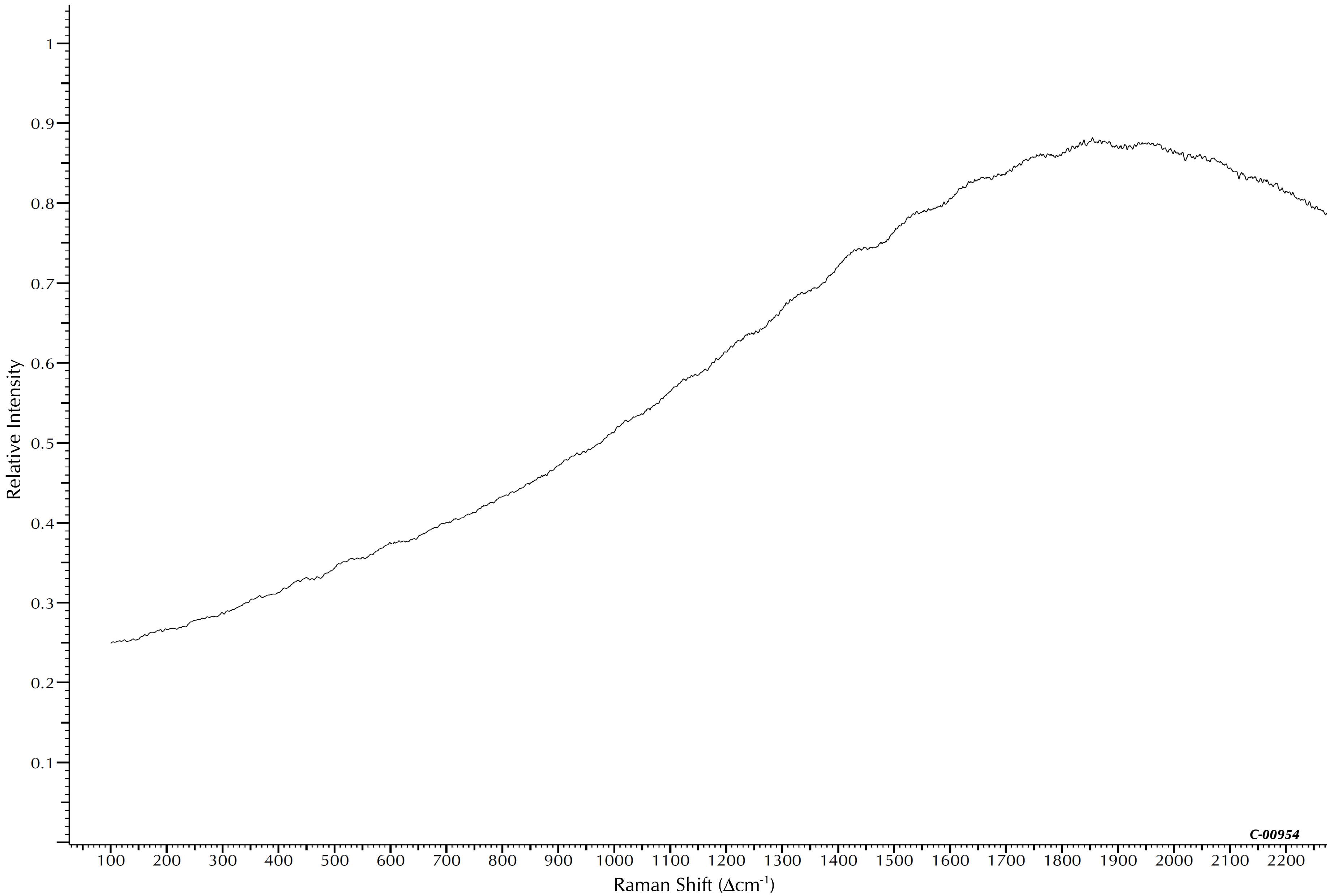
Chemical Category: Inorganic - Titanate
Constitution Number: 77543

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Black 26



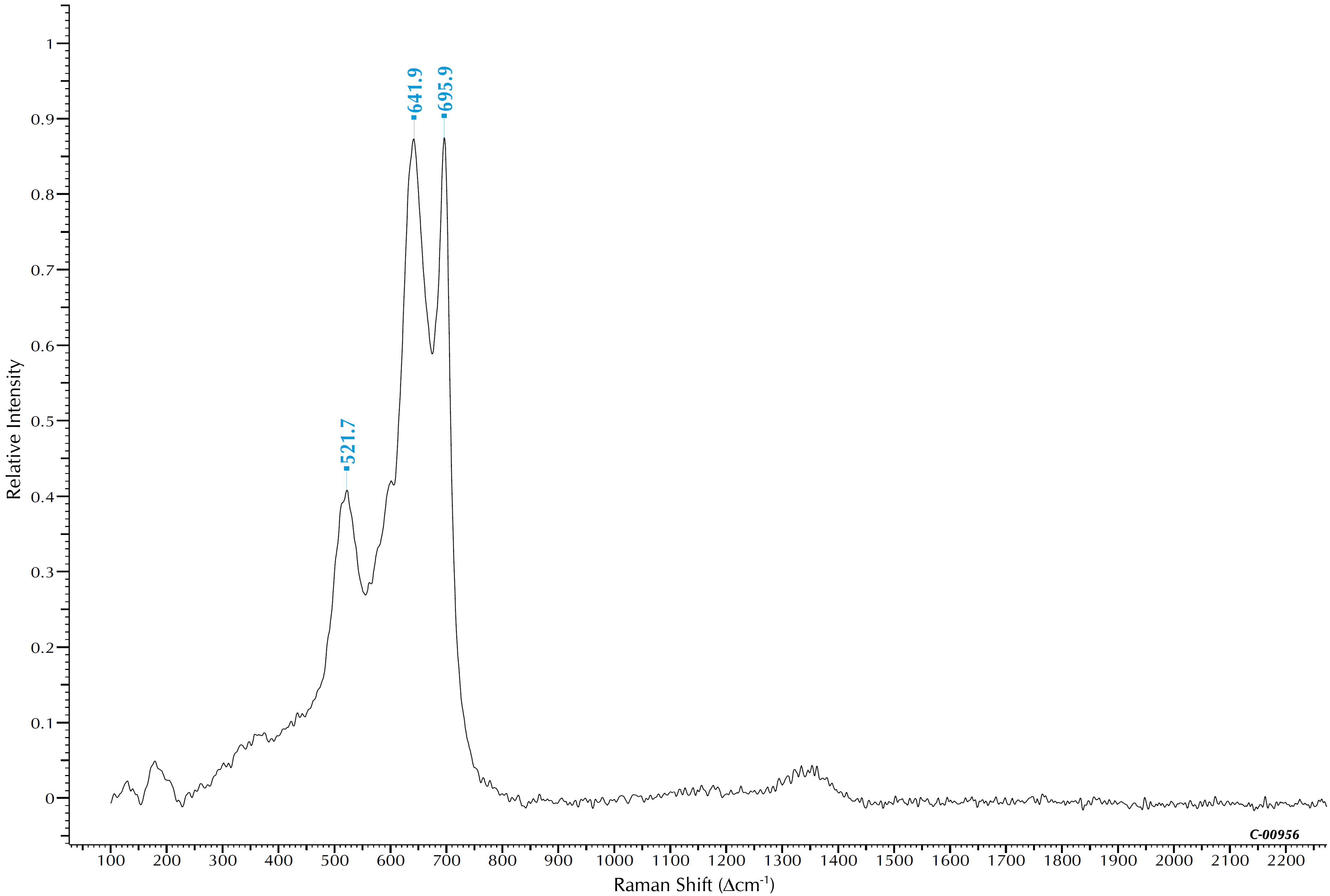
Chemical Category: Inorganic - Oxide
Constitution Number: 77494

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Black 30



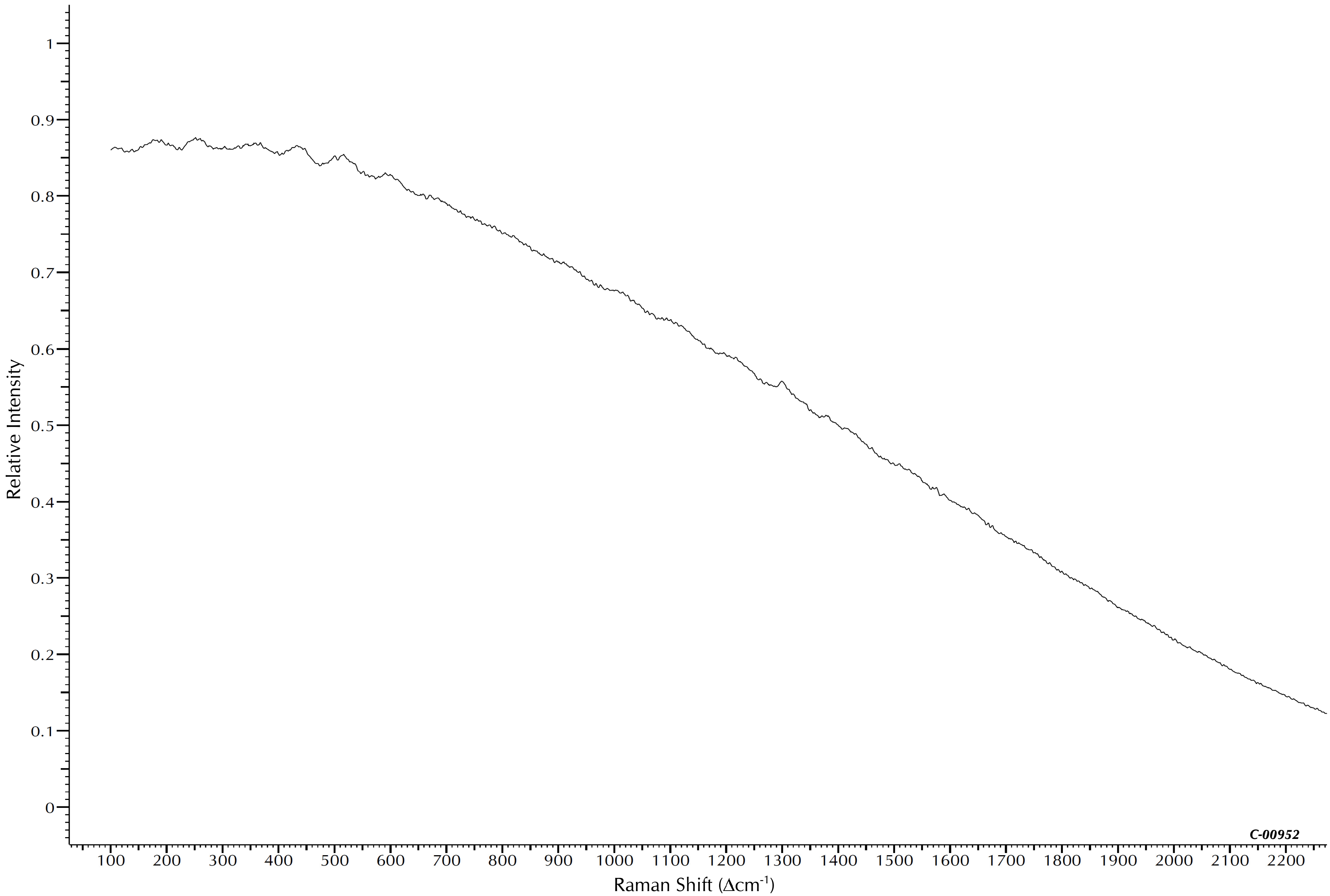
Chemical Category: Inorganic - Oxide
Constitution Number: 77504

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Black 32



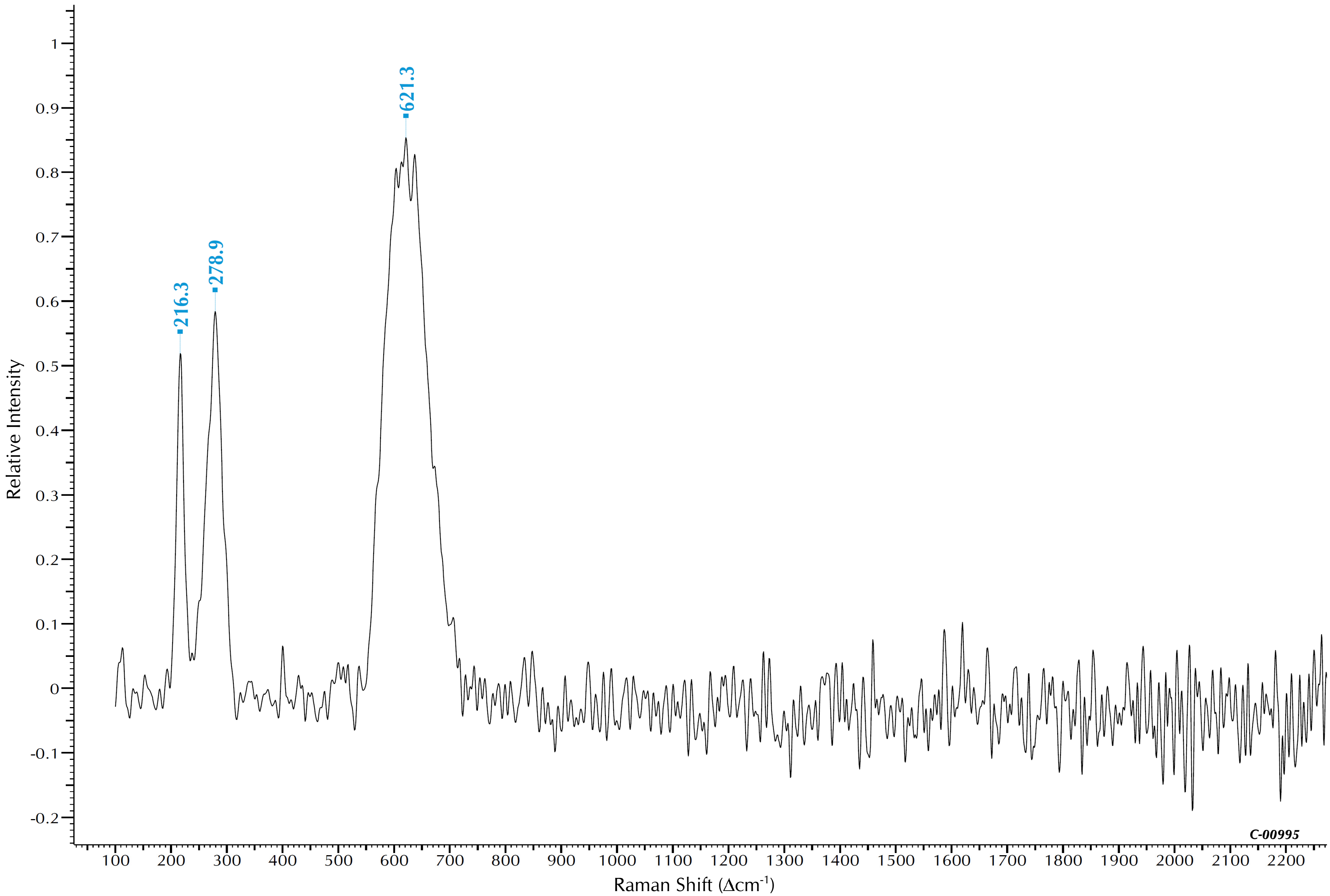
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71133

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.01
Quality Index 1

Microtrace LLC

C.I. Pigment Black 33



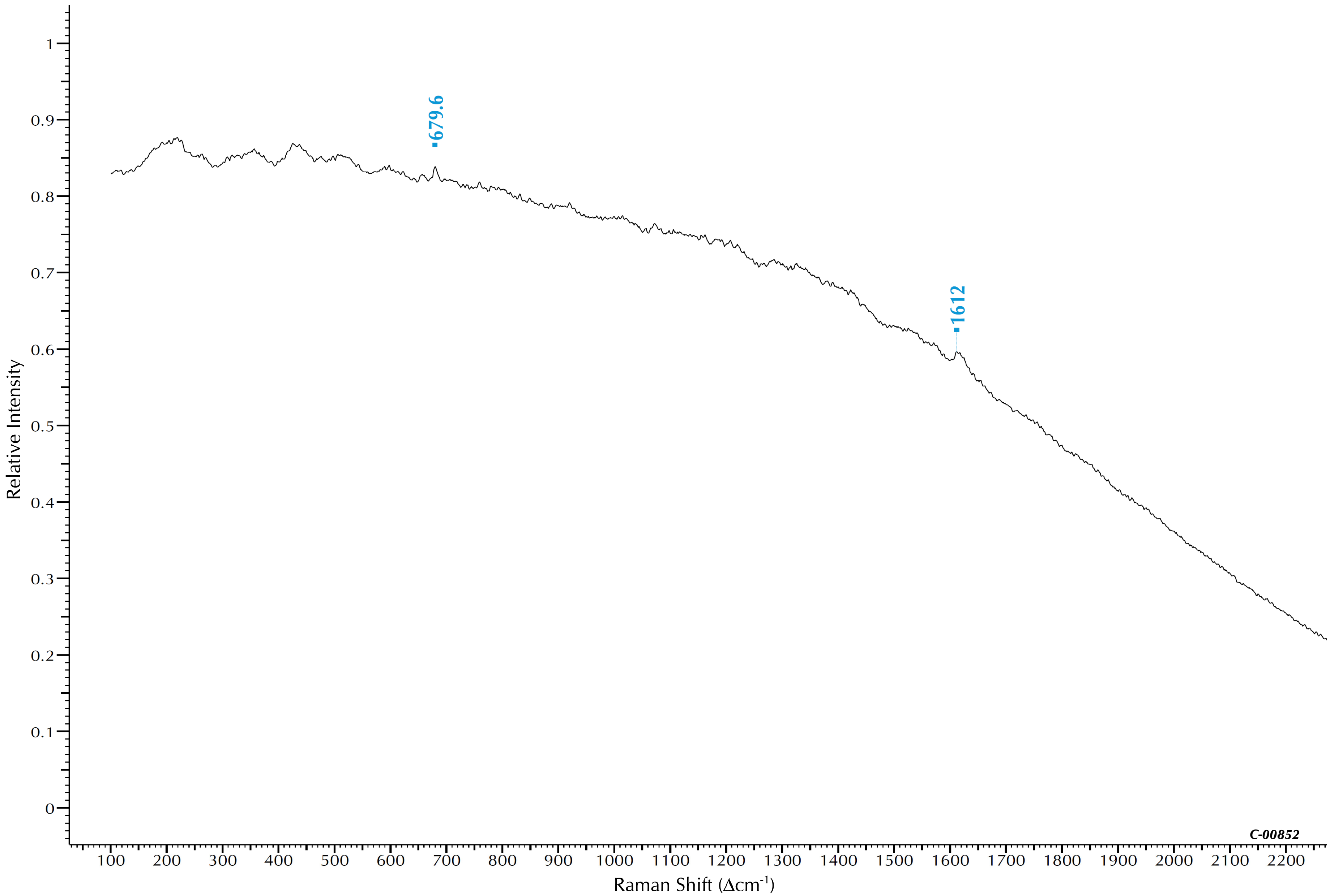
Chemical Category: Inorganic - Oxide
Constitution Number: 77537

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Blue 1



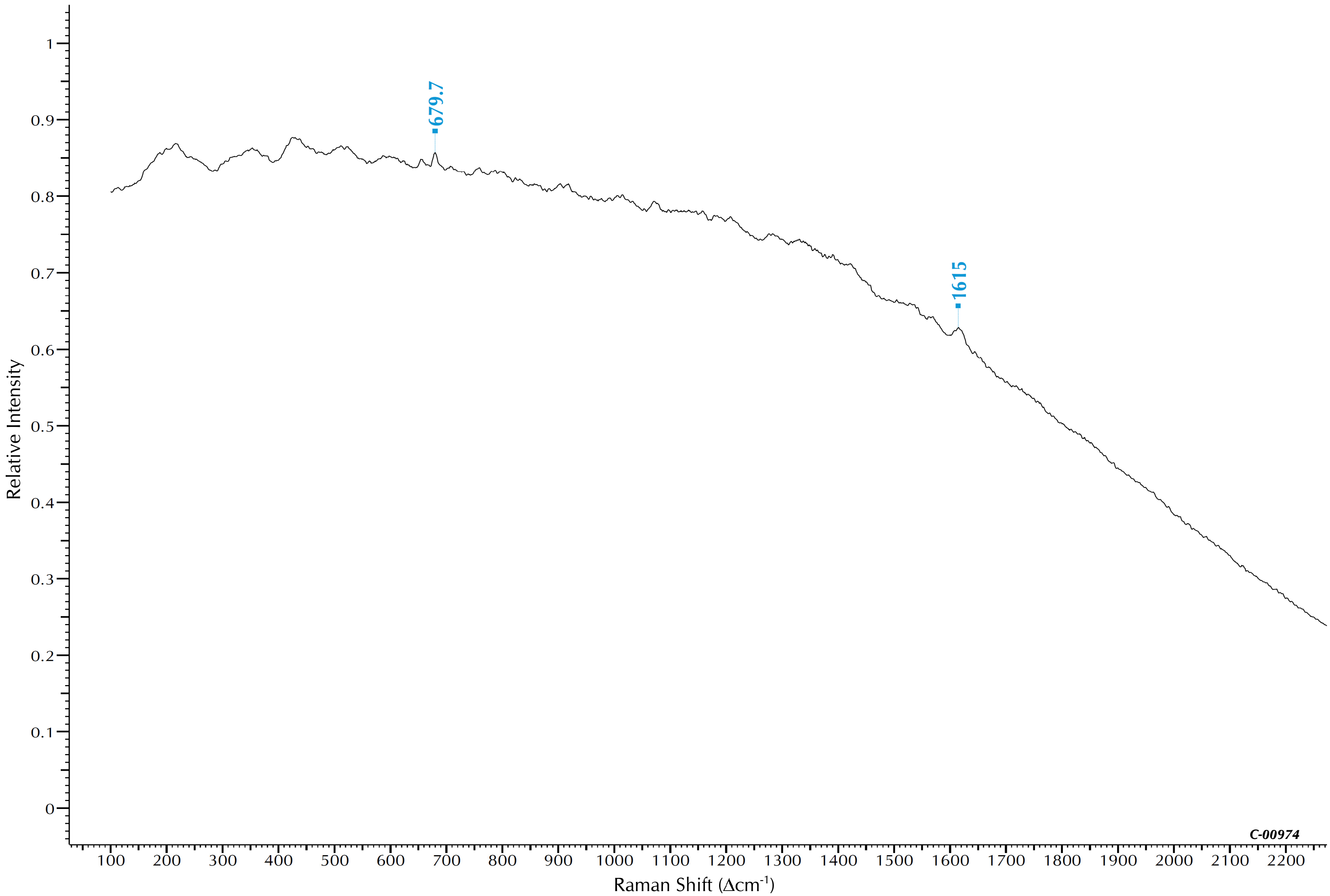
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42595:2

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Blue 1:2



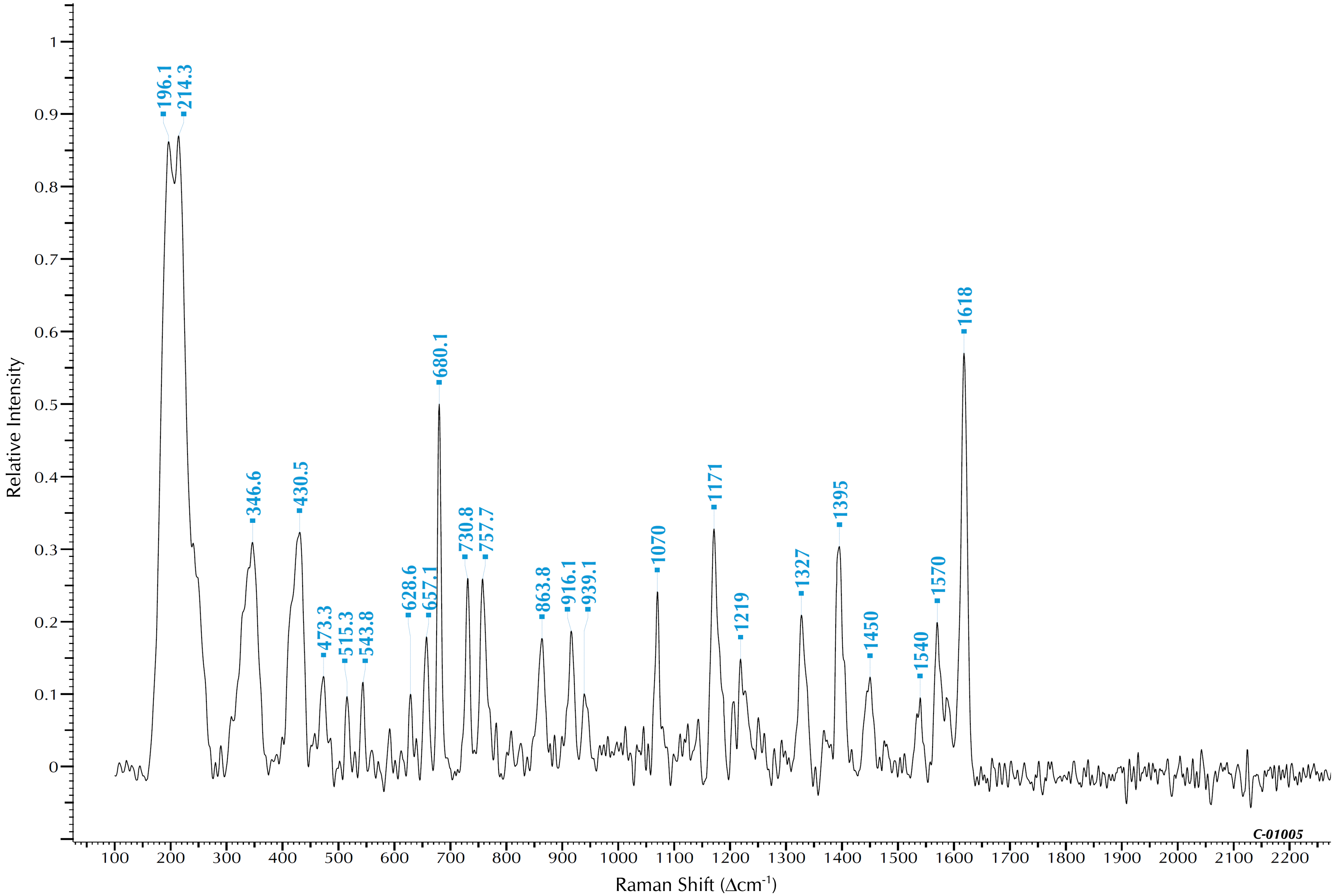
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42595:3

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 1

Microtrace LLC

C.I. Pigment Blue 10



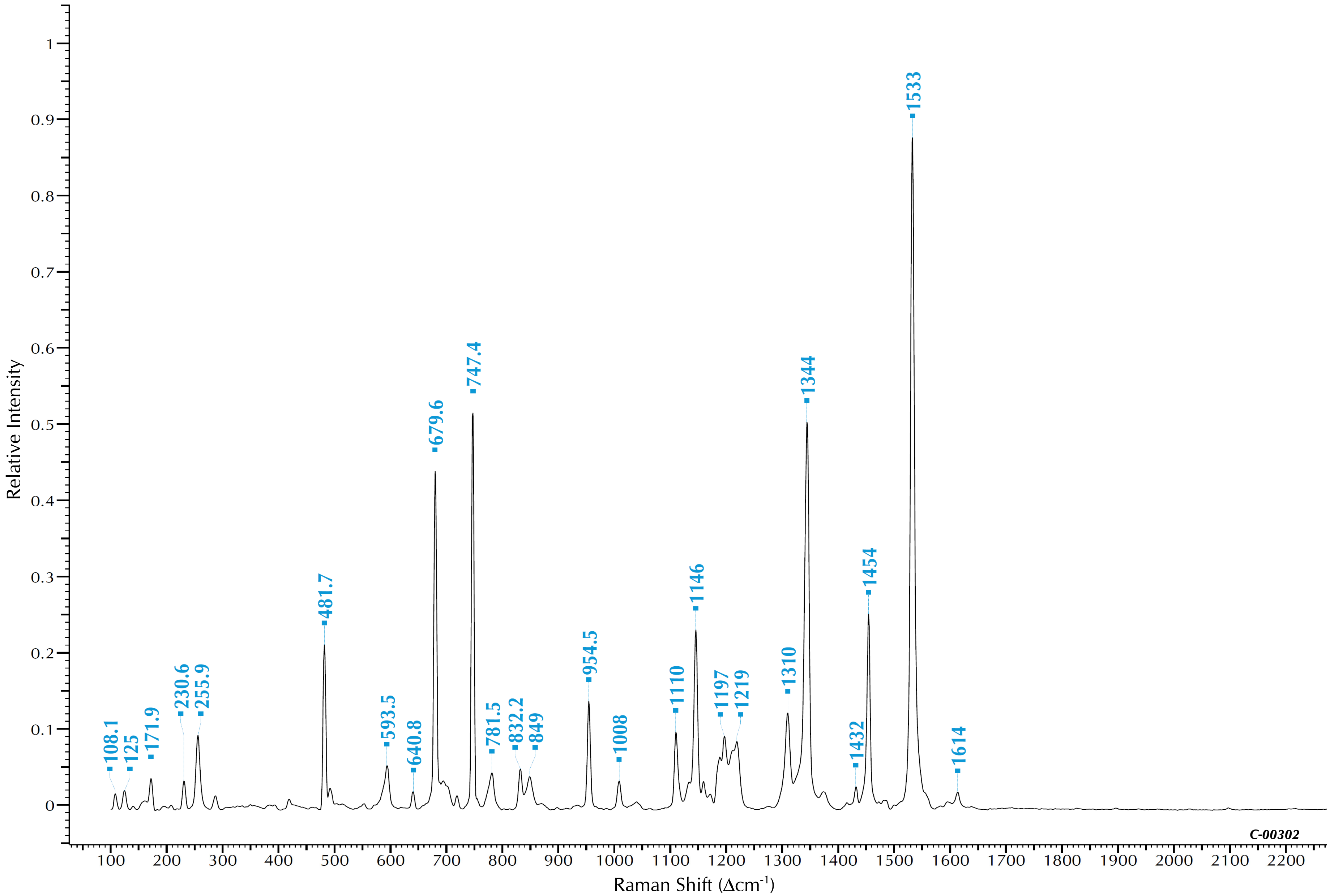
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 44040:2

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 1

Microtrace LLC

C.I. Pigment Blue 15



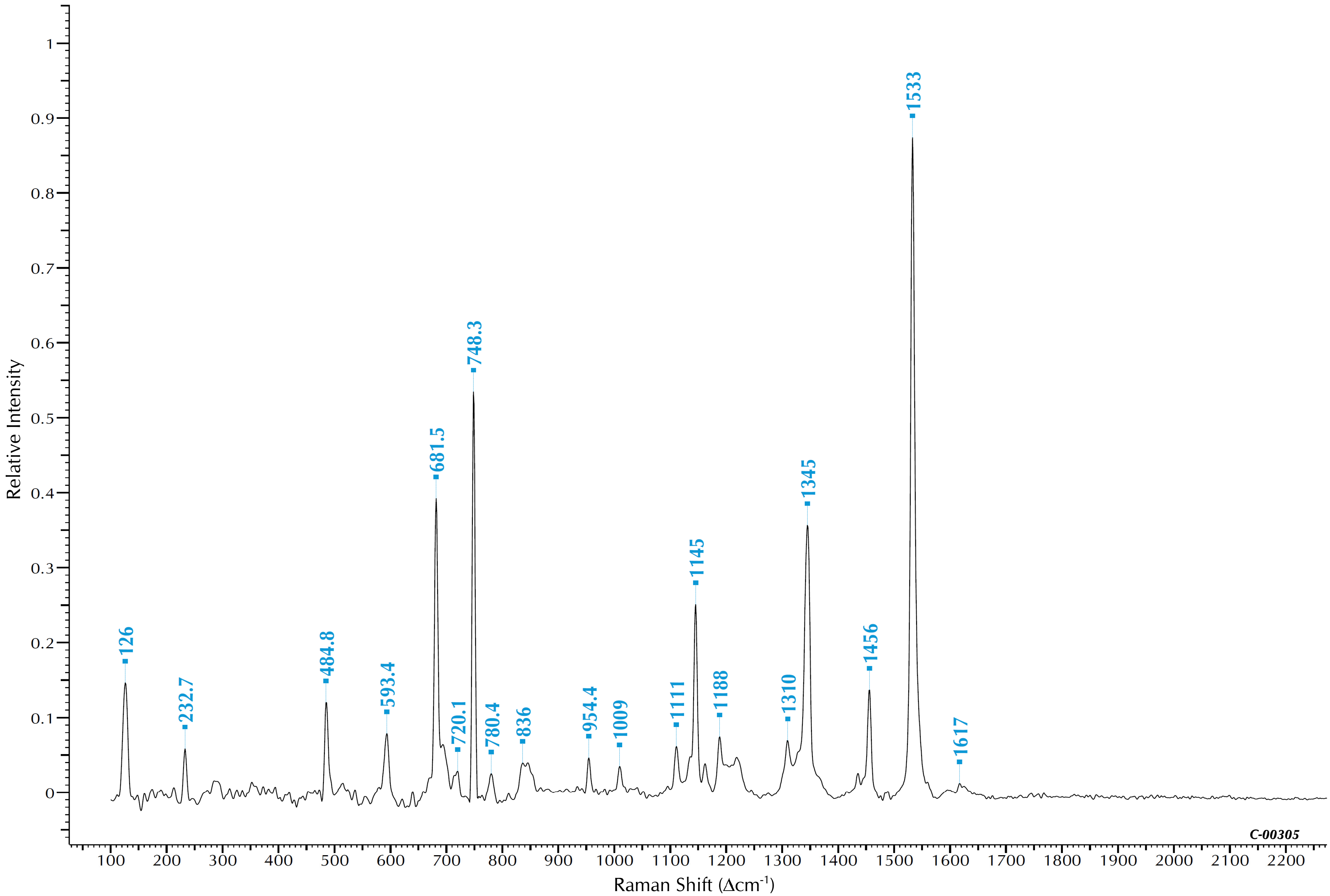
Chemical Category: Organic - Polycyclic - Phthalocyanine
Constitution Number: 74160

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Blue 15:1



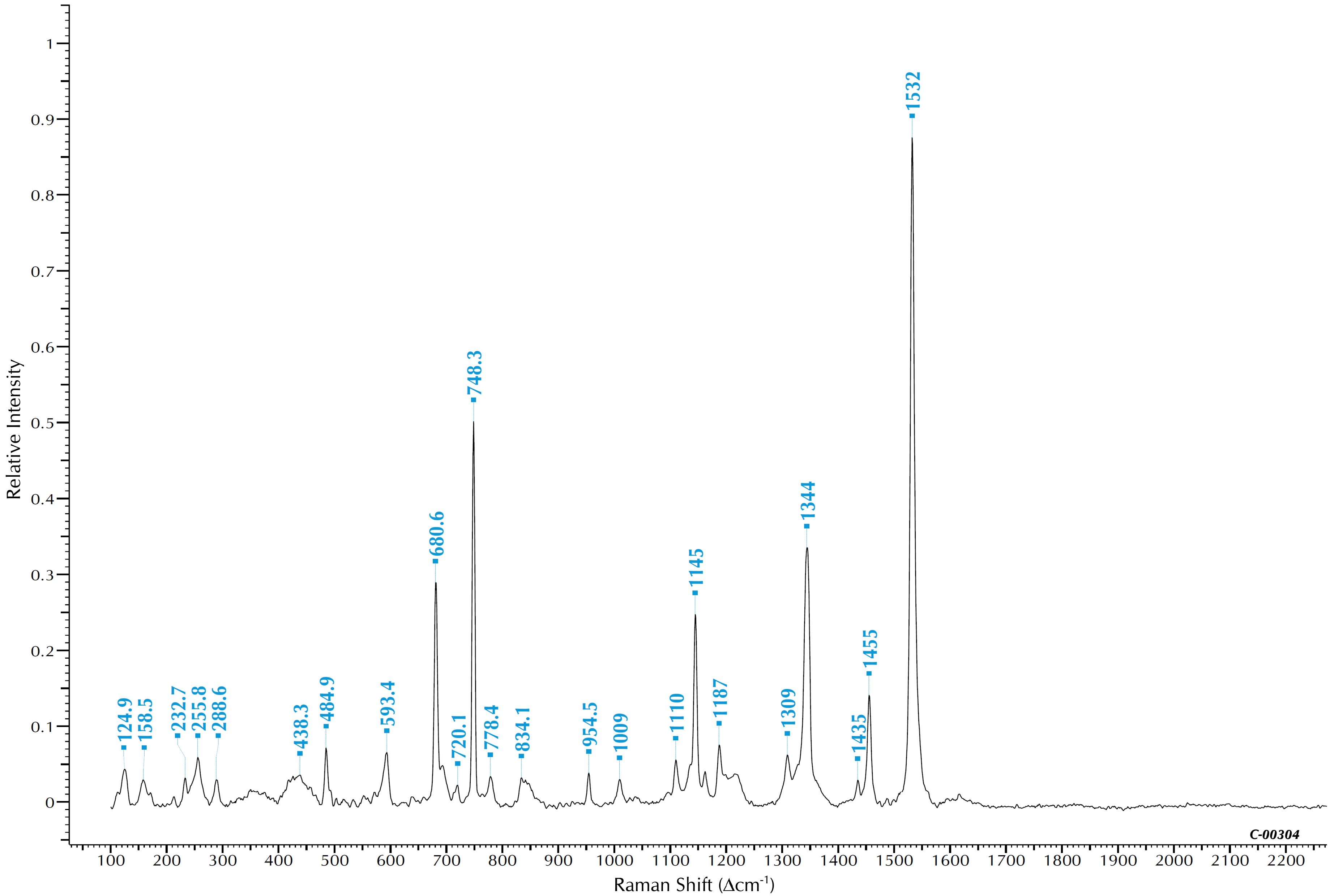
Chemical Category: Organic - Polycyclic - Phthalocyanine - alpha
Constitution Number: 74160

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Blue 15:2



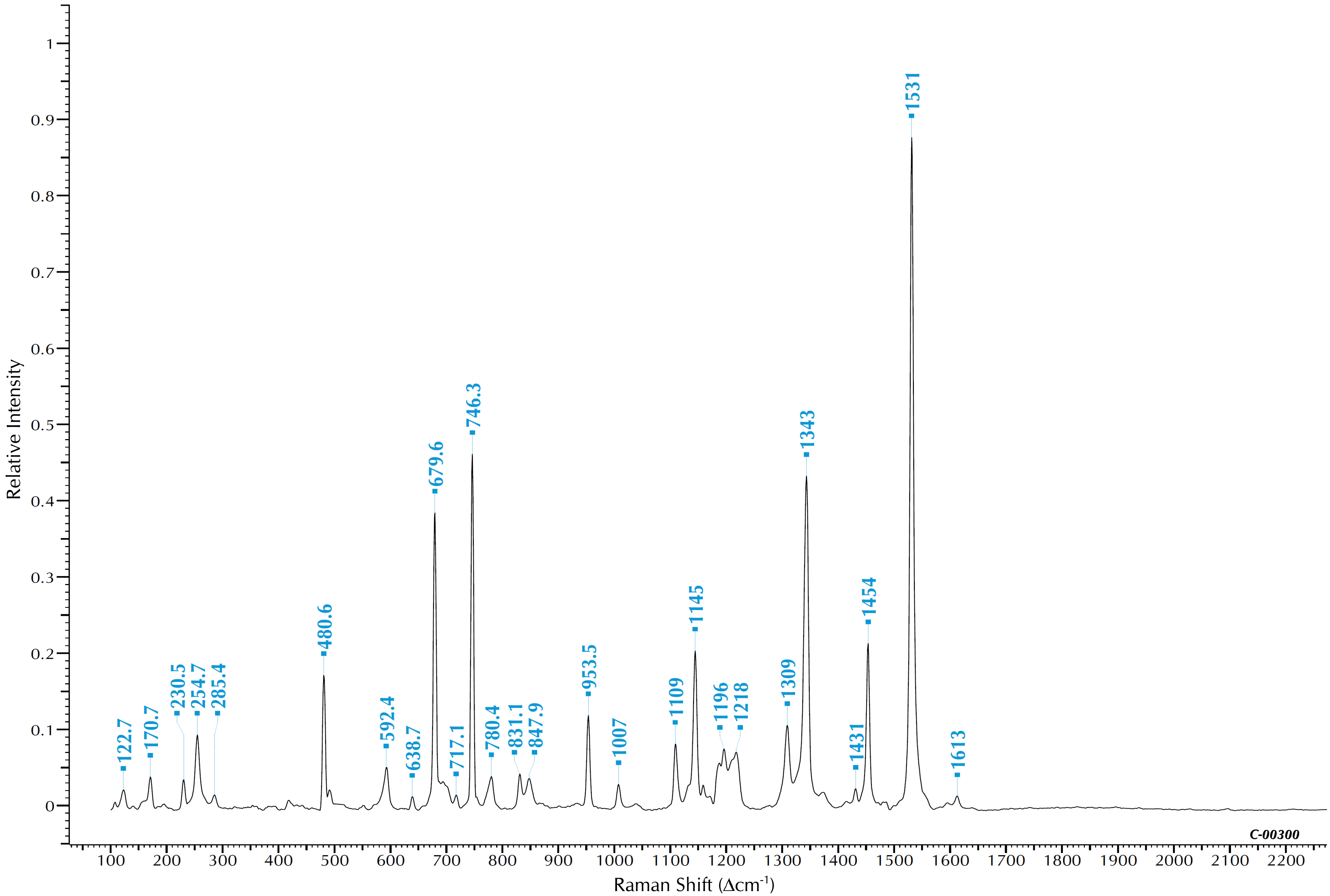
Chemical Category: Organic - Polycyclic - Phthalocyanine - alpha
Constitution Number: 74160

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Blue 15:3



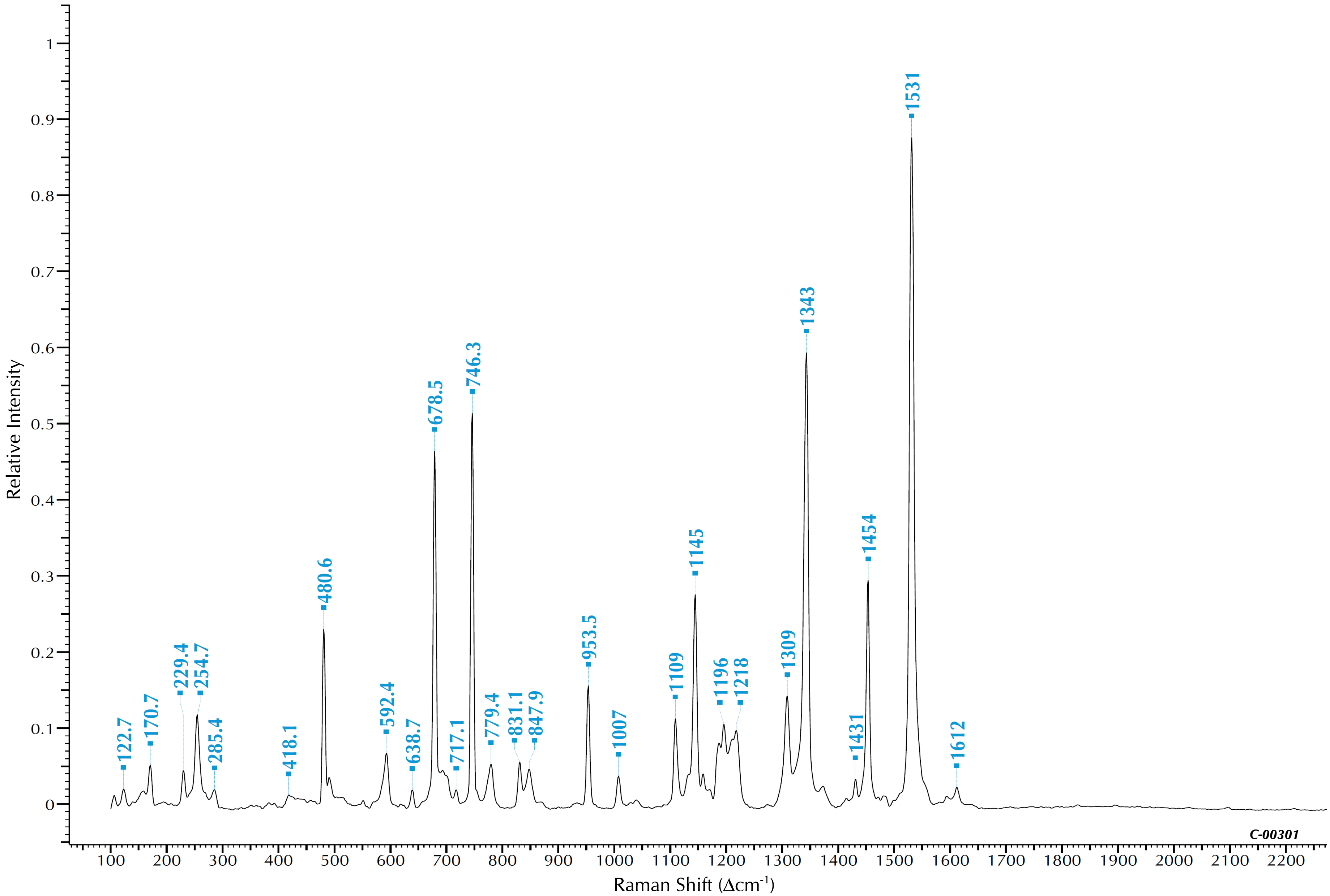
Chemical Category: Organic - Polycyclic - Phthalocyanine - beta
Constitution Number: 74160

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Blue 15:4



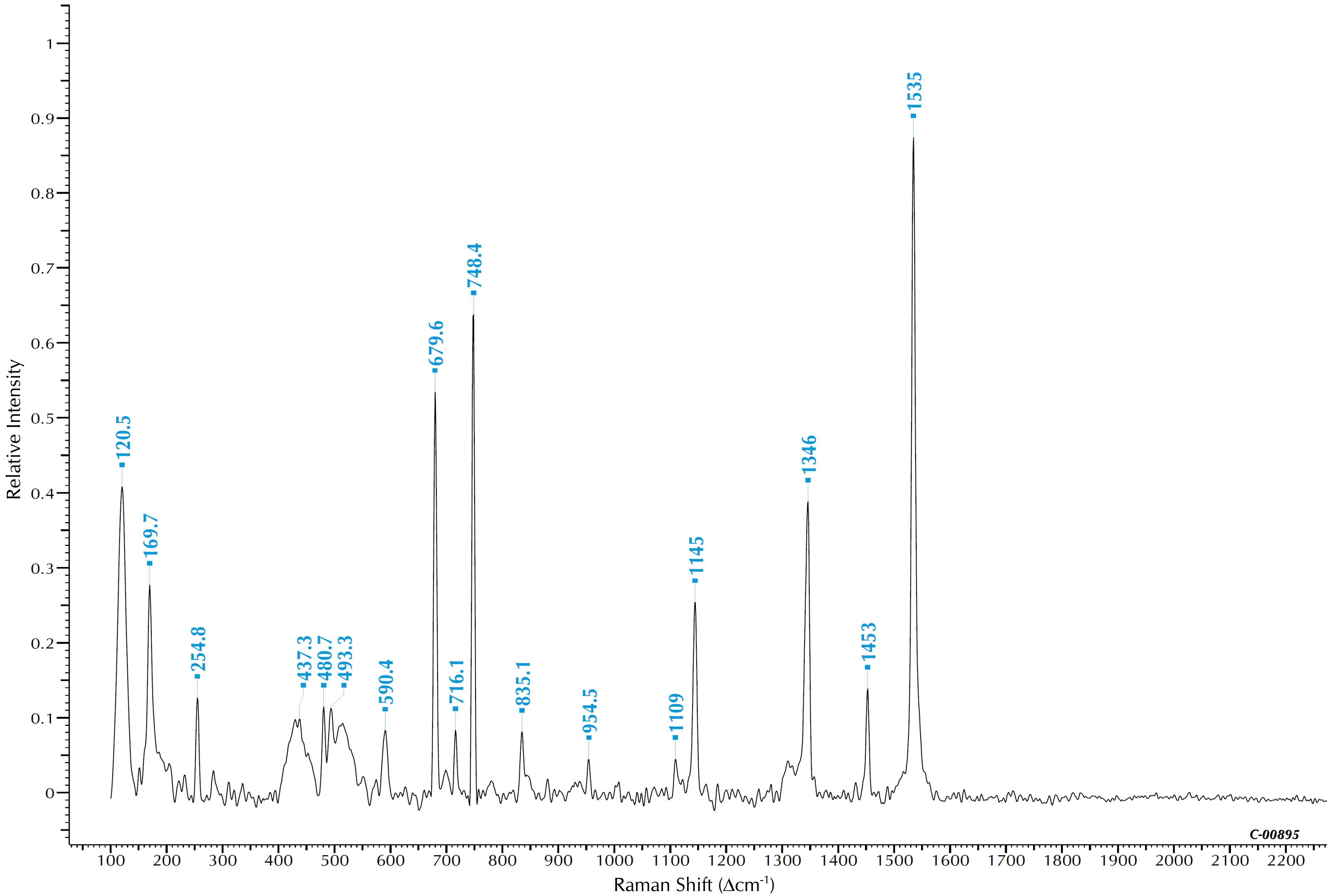
Chemical Category: Organic - Polycyclic - Phthalocyanine - beta
Constitution Number: 74160

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Blue 15:6



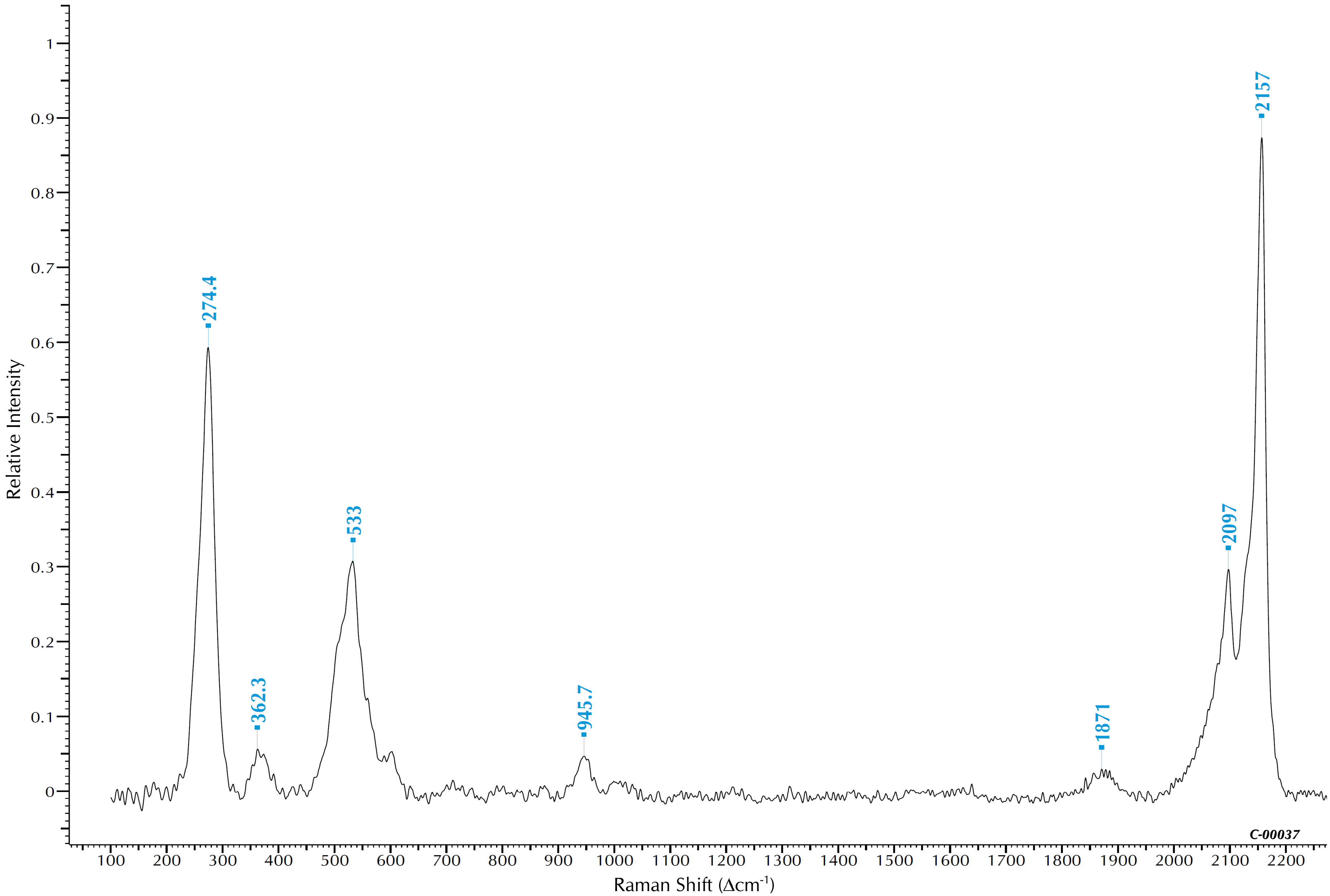
Chemical Category: Organic - Polycyclic - Phthalocyanine - gamma
Constitution Number: 74160

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.01
Quality Index 2

Microtrace LLC

C.I. Pigment Blue 27



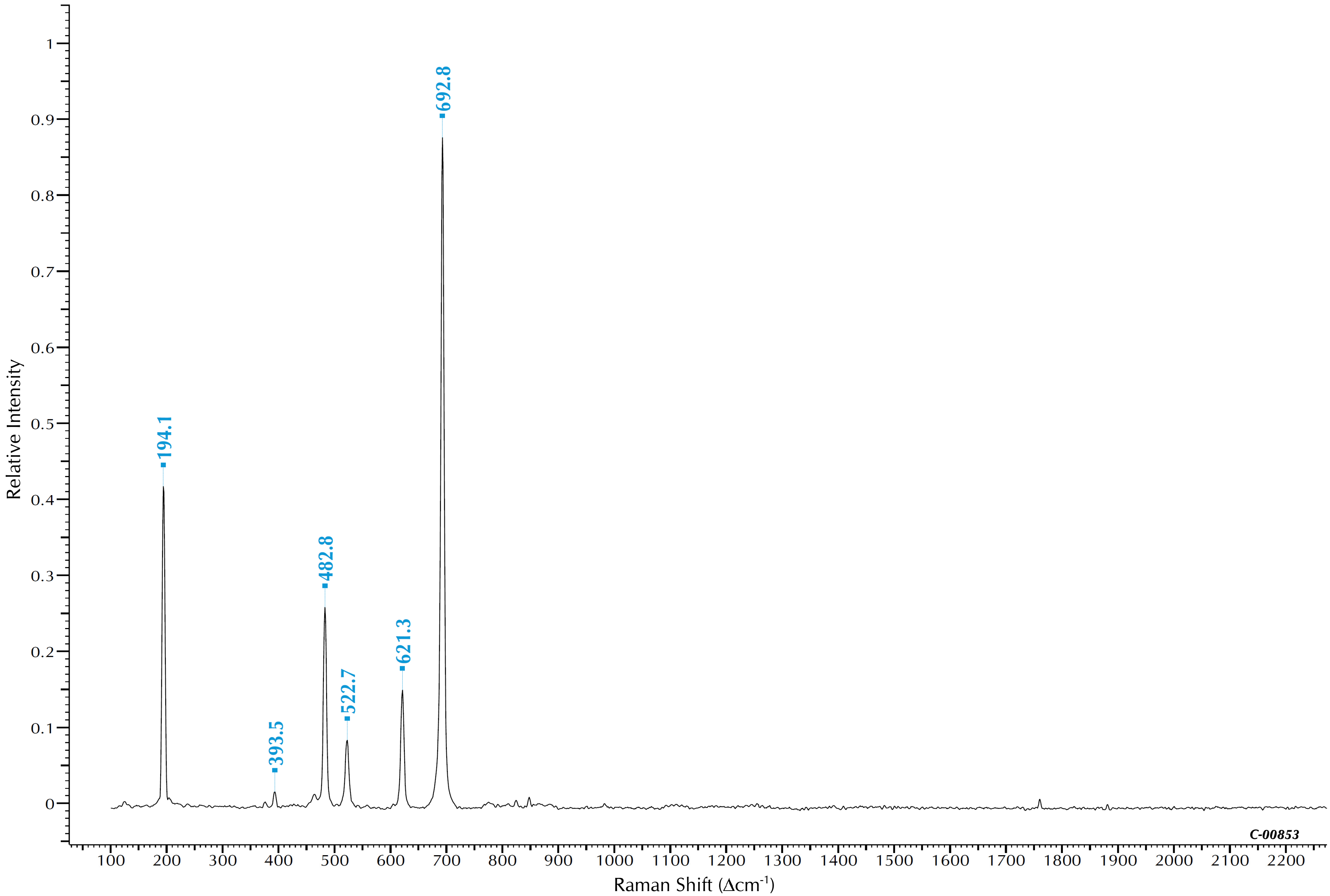
Chemical Category: Inorganic - Cyanide
Constitution Number: 77510

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Blue 28



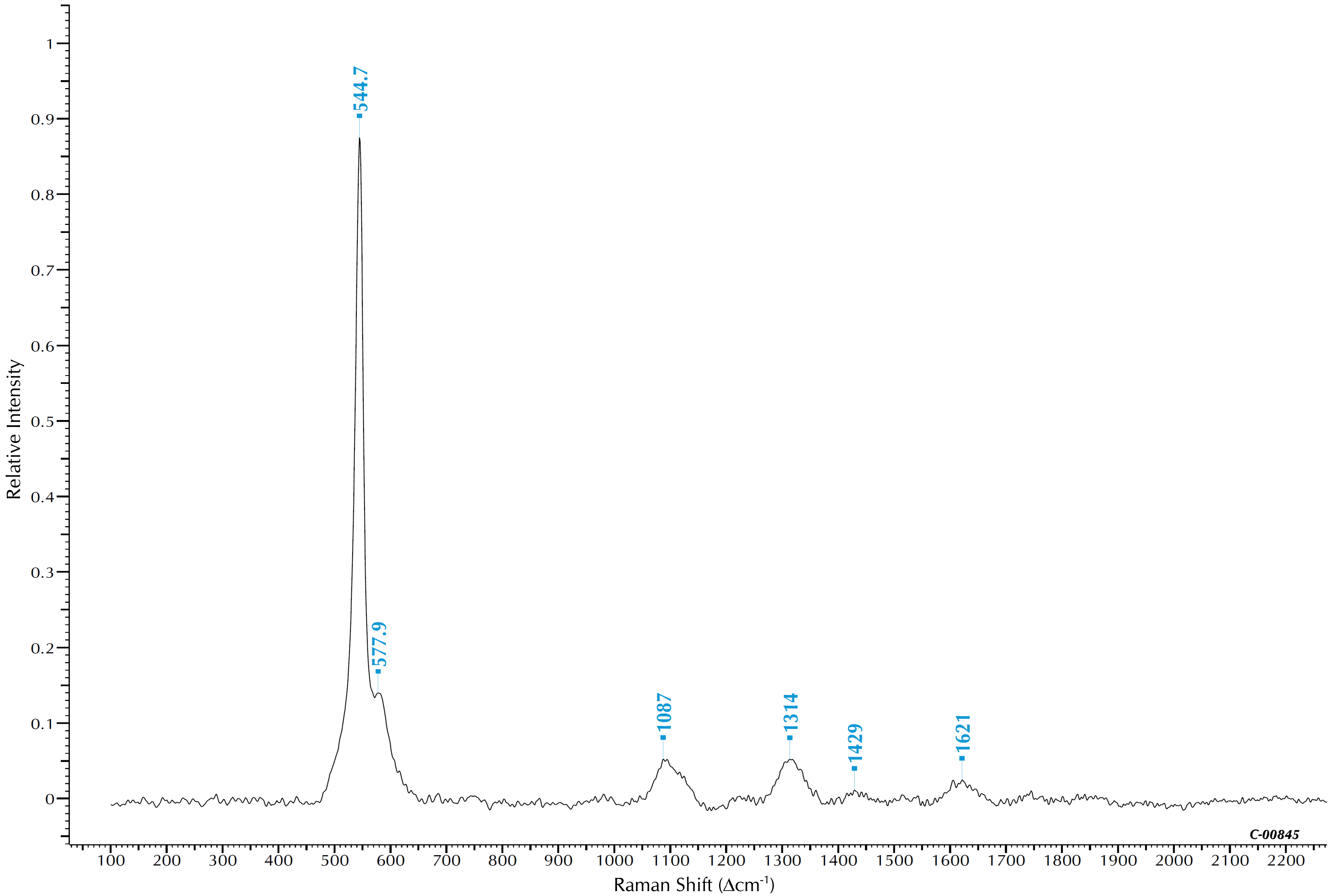
Chemical Category: Inorganic - Aluminate
Constitution Number: 77346

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Blue 29



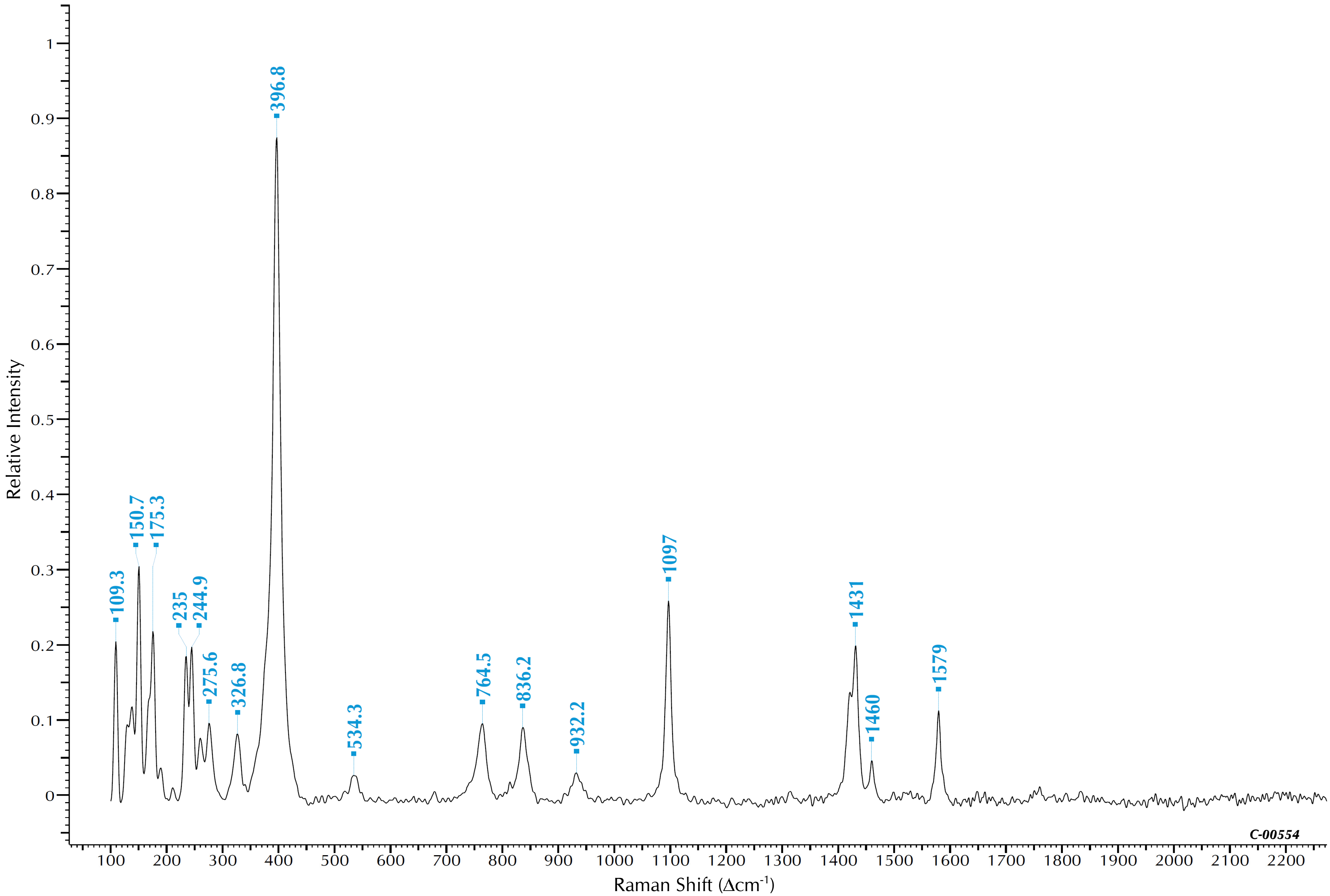
Chemical Category: Inorganic - Sulfide
Constitution Number: 77007

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Blue 30



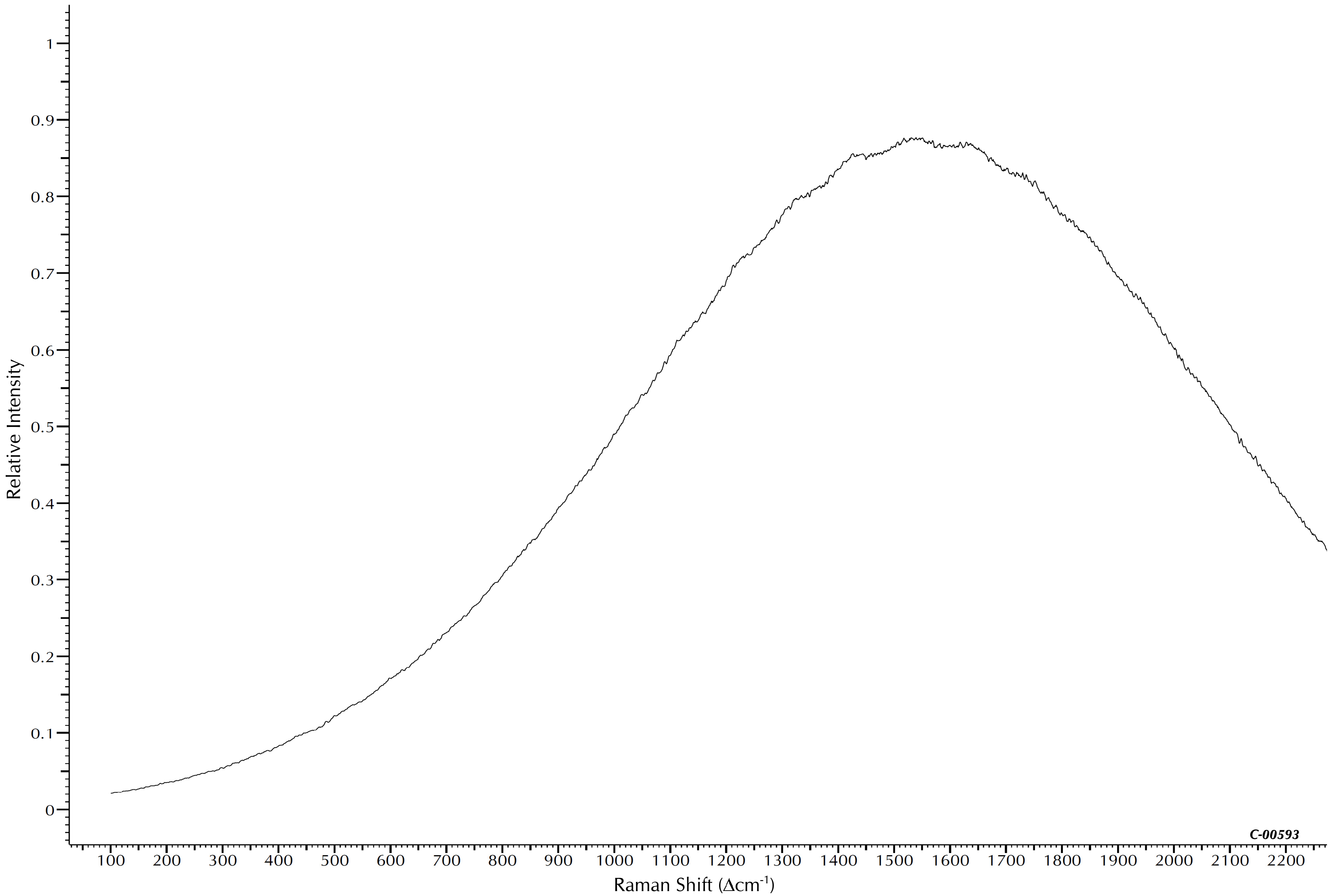
Chemical Category: Inorganic - Hydroxide
Constitution Number: 77420

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Blue 31



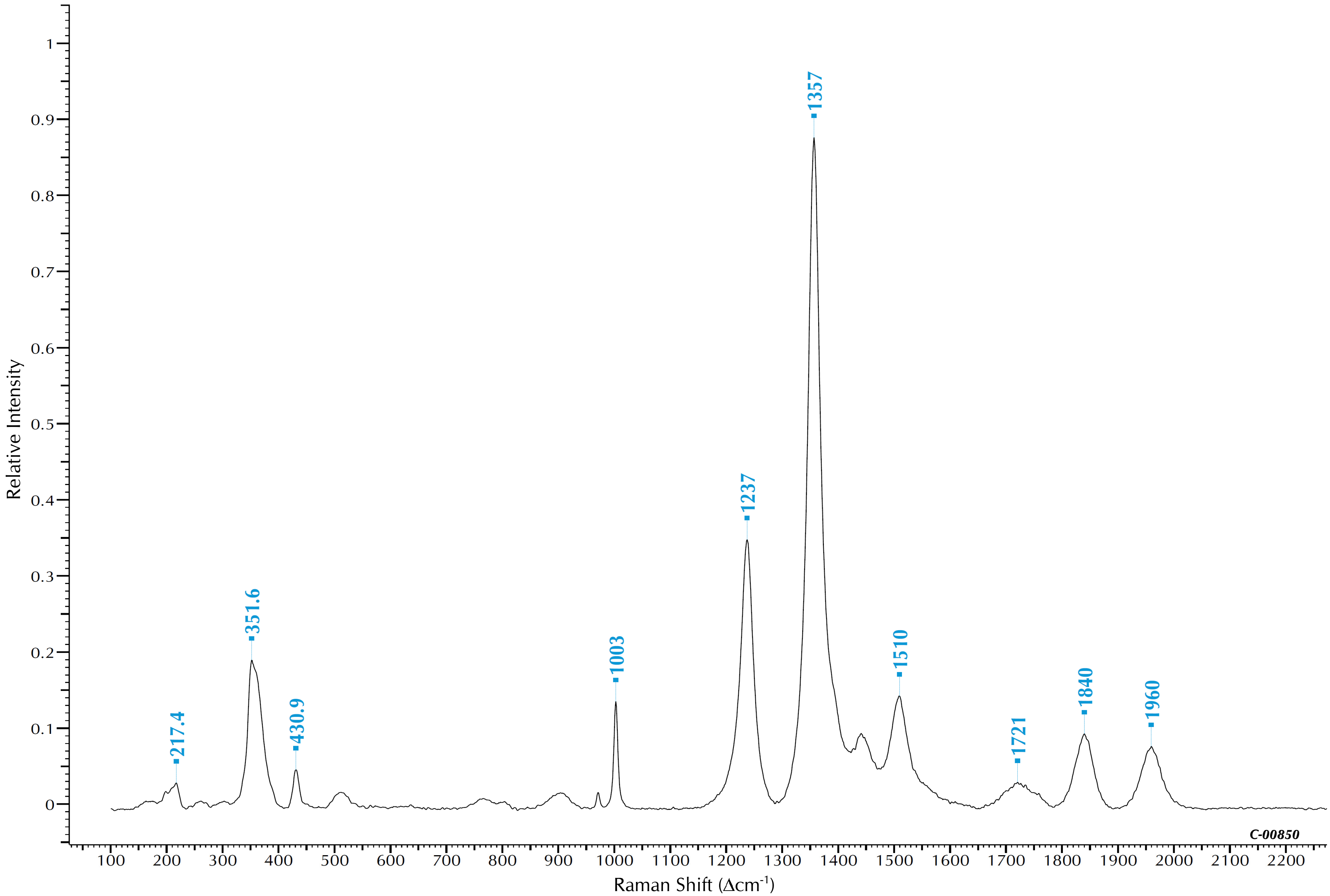
Chemical Category: Inorganic - Silicate
Constitution Number: 77437

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.00011
Quality Index 5

Microtrace LLC

C.I. Pigment Blue 35



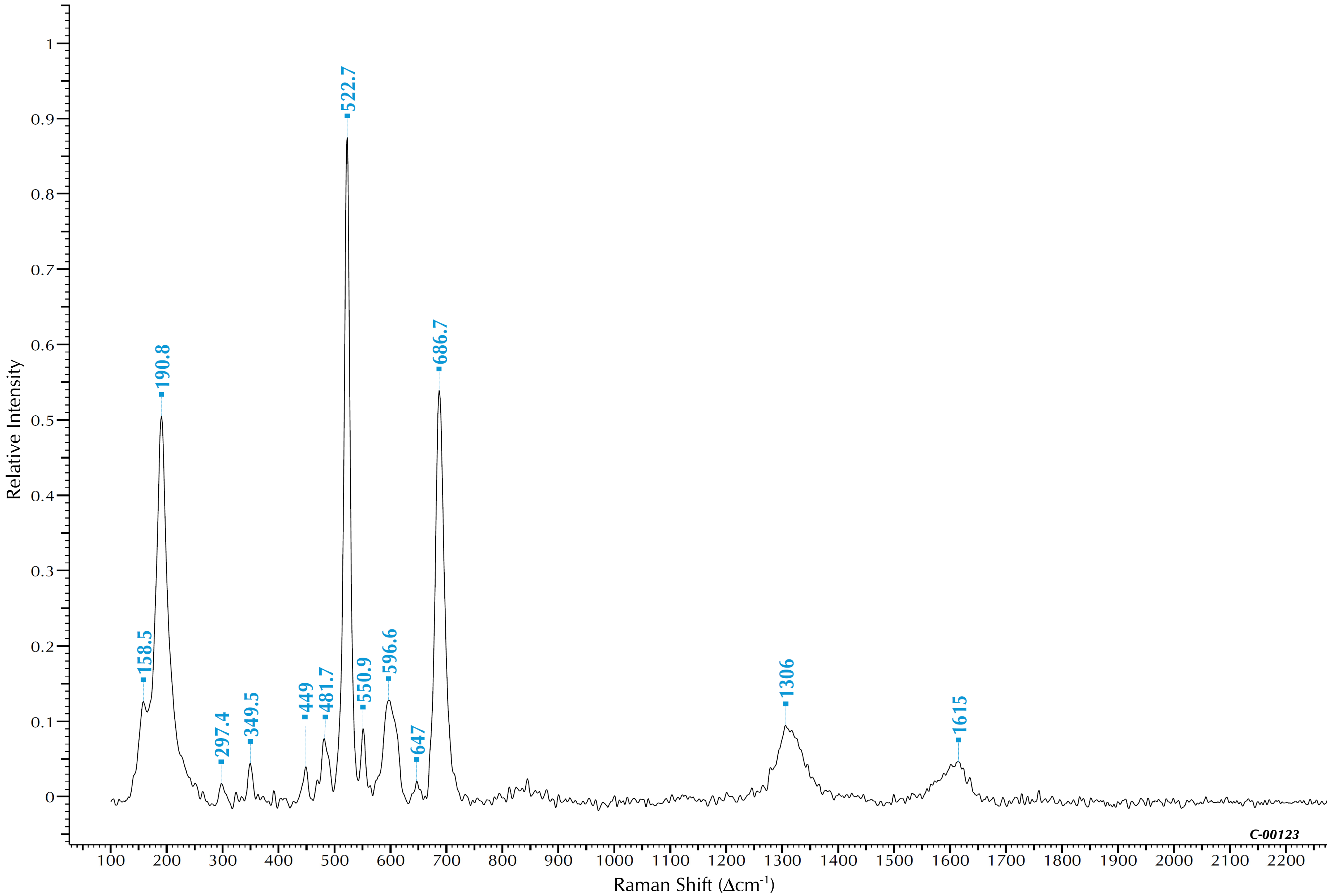
Chemical Category: Inorganic - Stannate
Constitution Number: 77368

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Blue 36



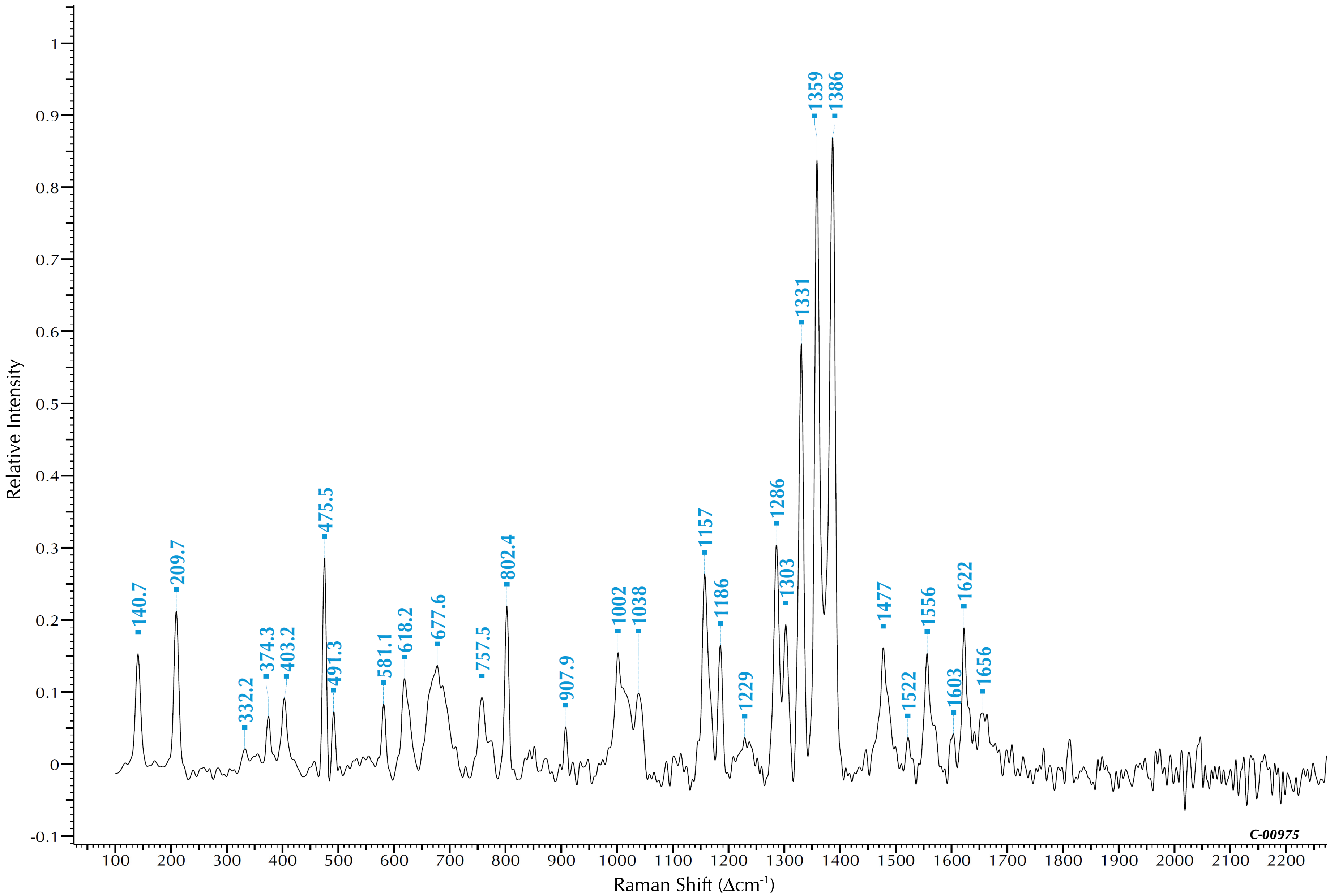
Chemical Category: Inorganic - Oxide
Constitution Number: 77343

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Blue 60



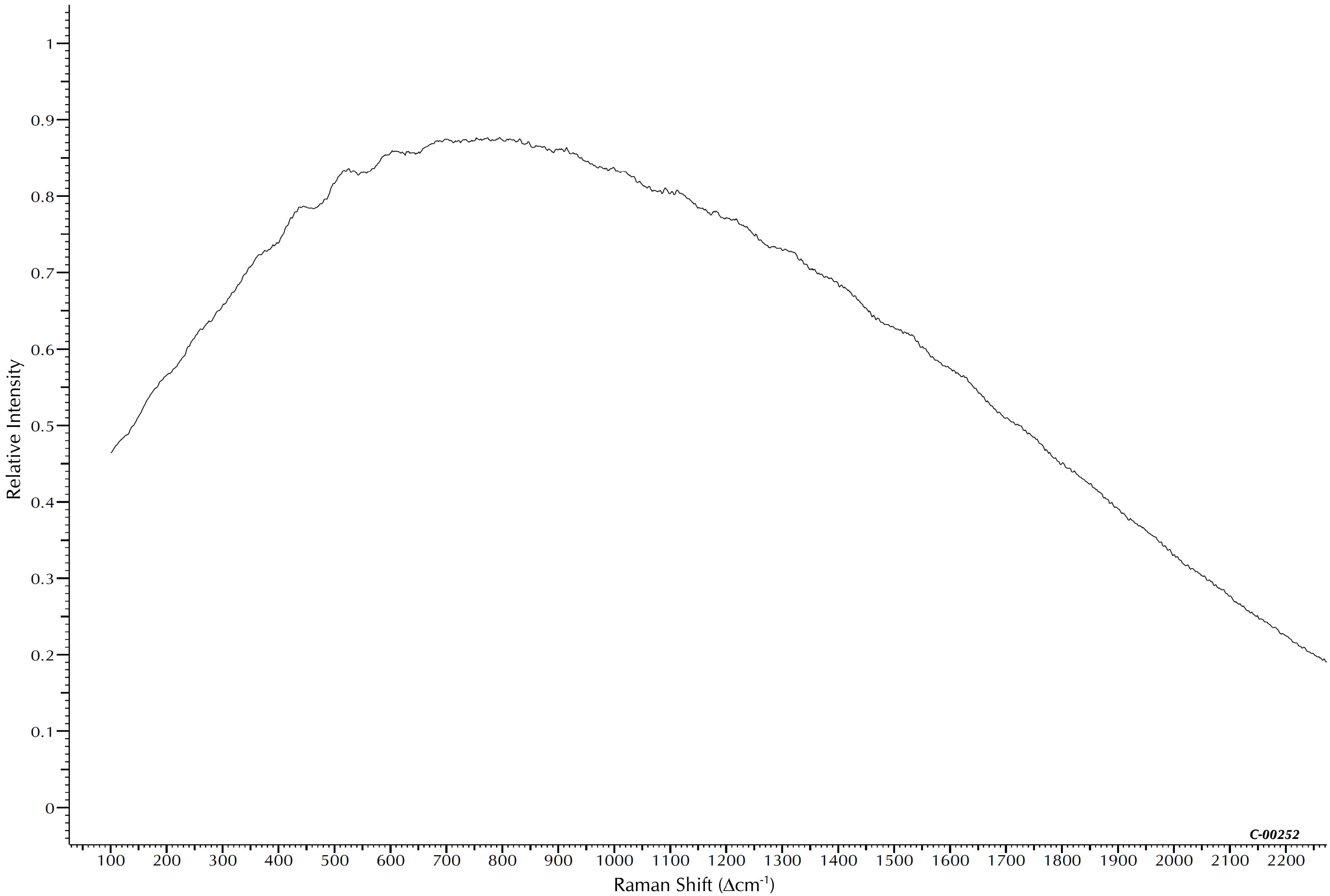
Chemical Category: Organic - Polycyclic - Heterocyclic Anthraquinone - Indanthrone
Constitution Number: 69800

Bleaching Time (s): 600
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 1

Microtrace LLC

C.I. Pigment Blue 61



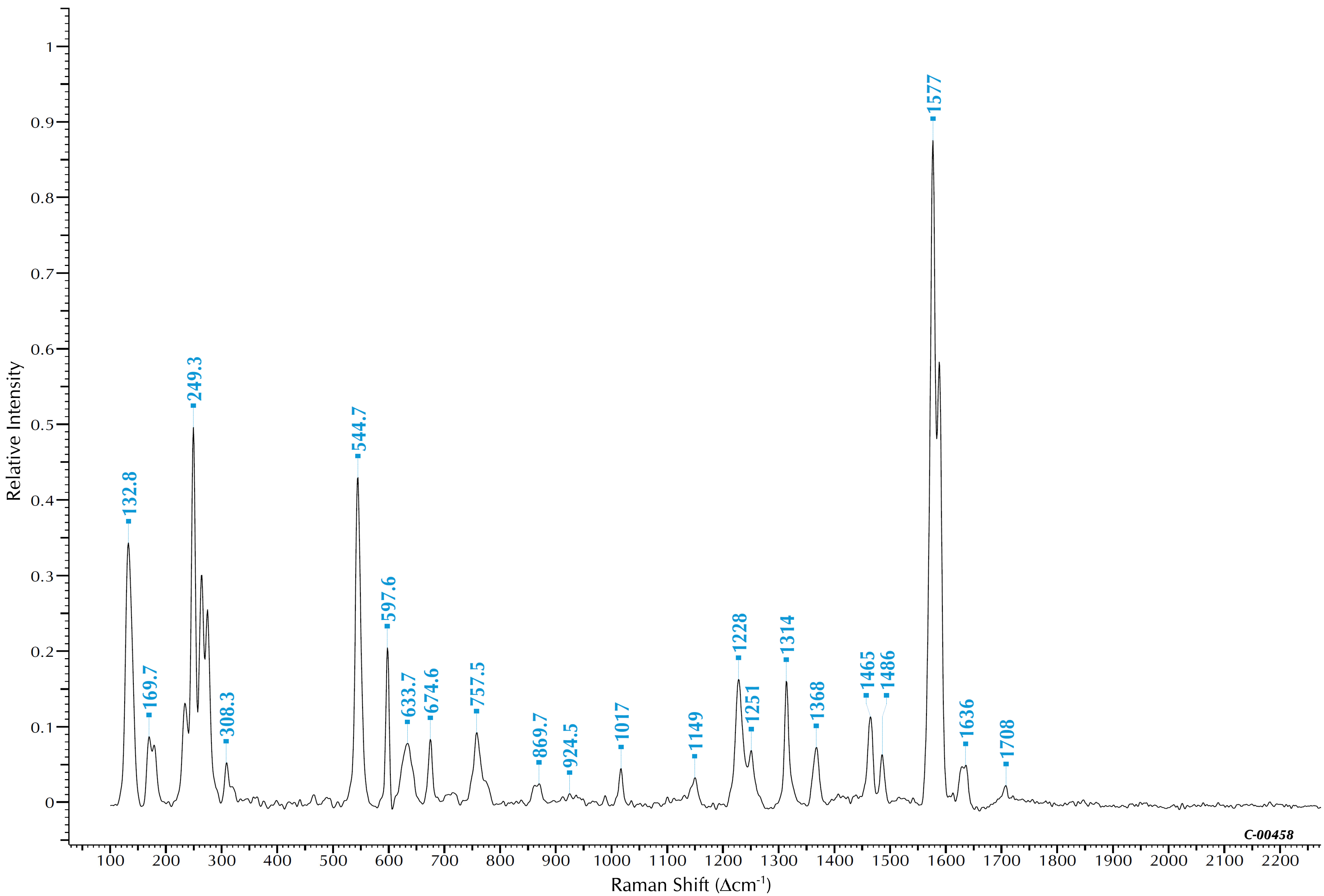
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Inner salts of sulfonic acid
Constitution Number: 42765:1

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.01
Quality Index 3

Microtrace LLC

C.I. Pigment Blue 66



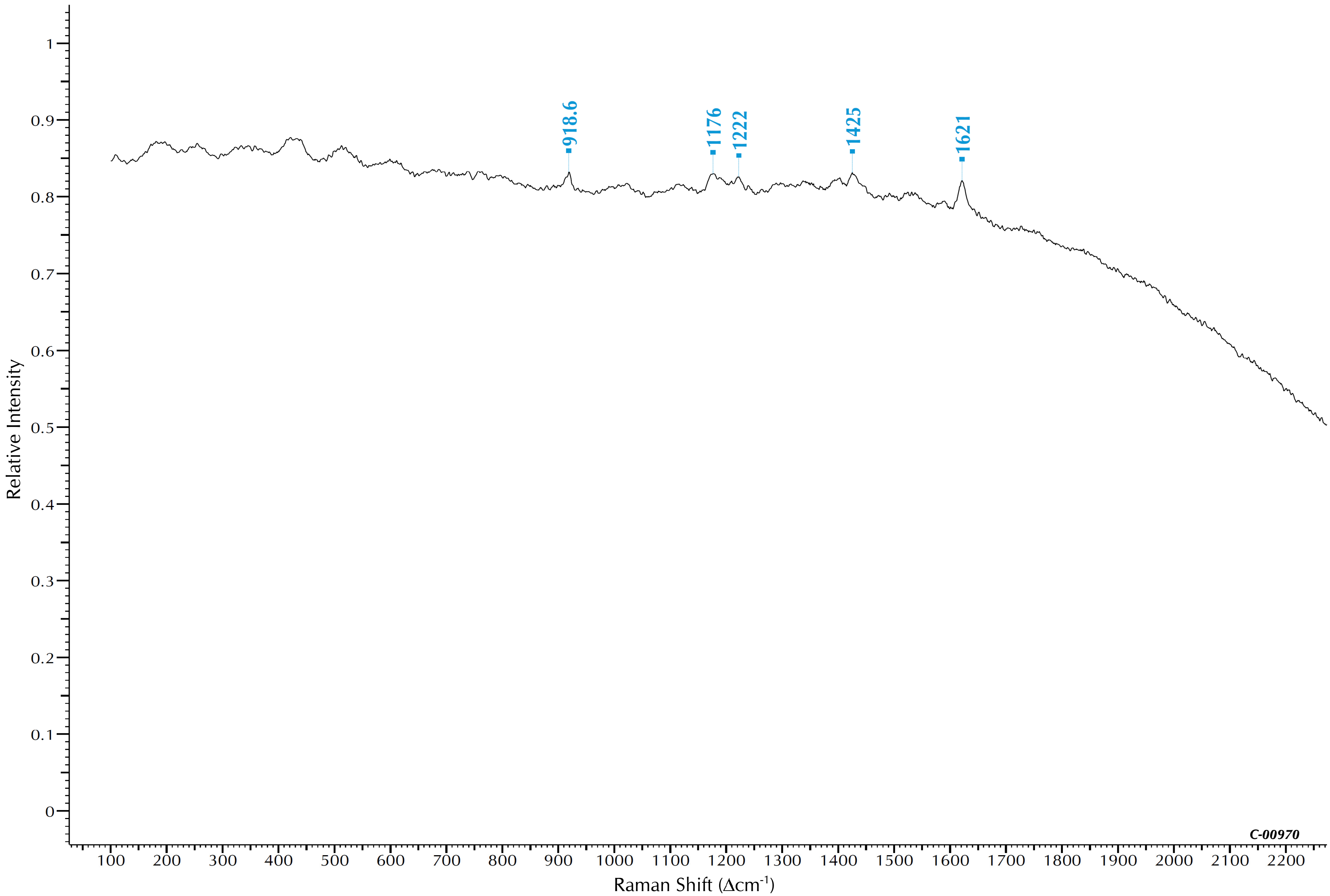
Chemical Category: Organic - Polycyclic - Thioindigo - Indigo, unsubstituted
Constitution Number: 73000

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 4

Microtrace LLC

C.I. Pigment Blue 78



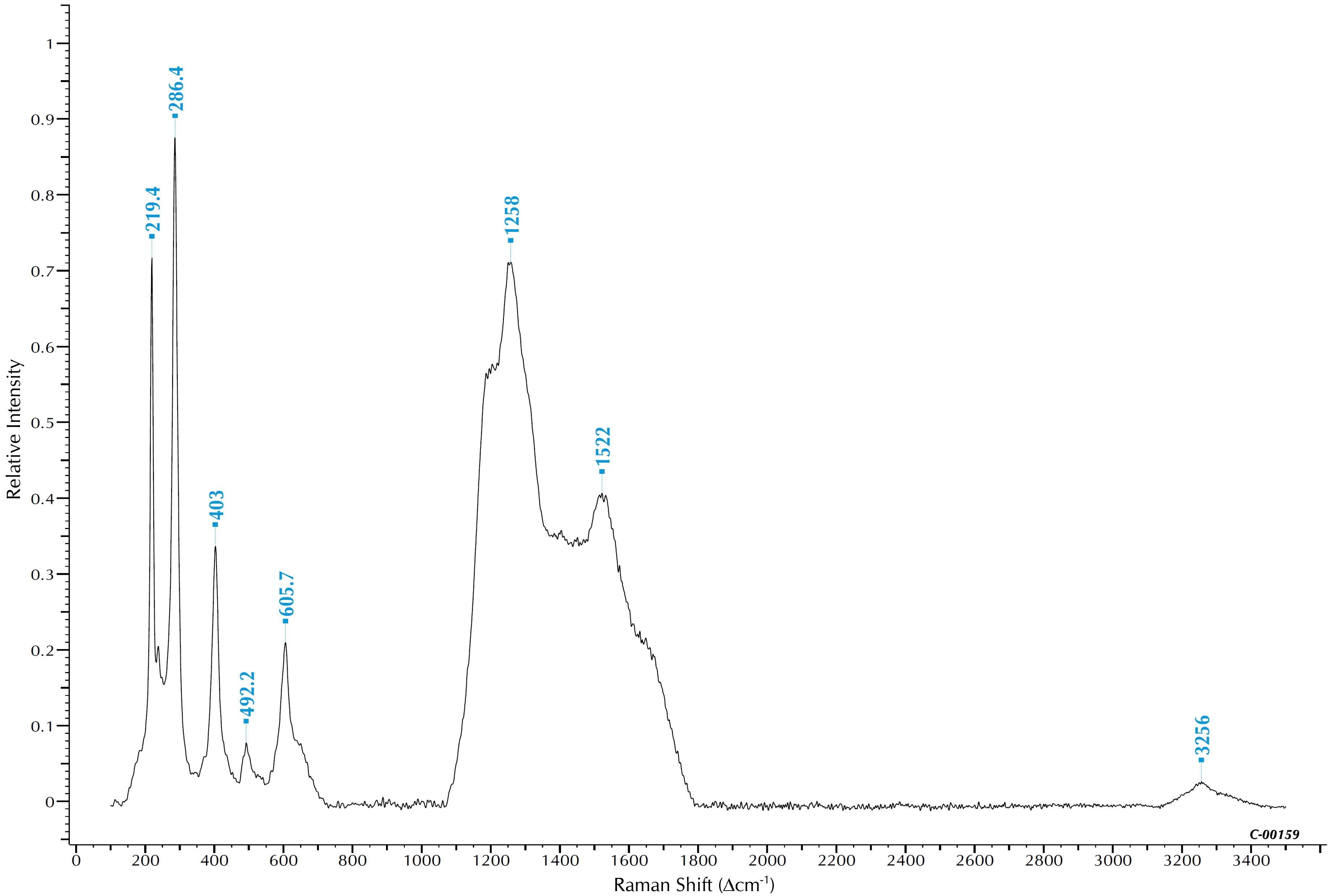
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42090:2

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Brown 6



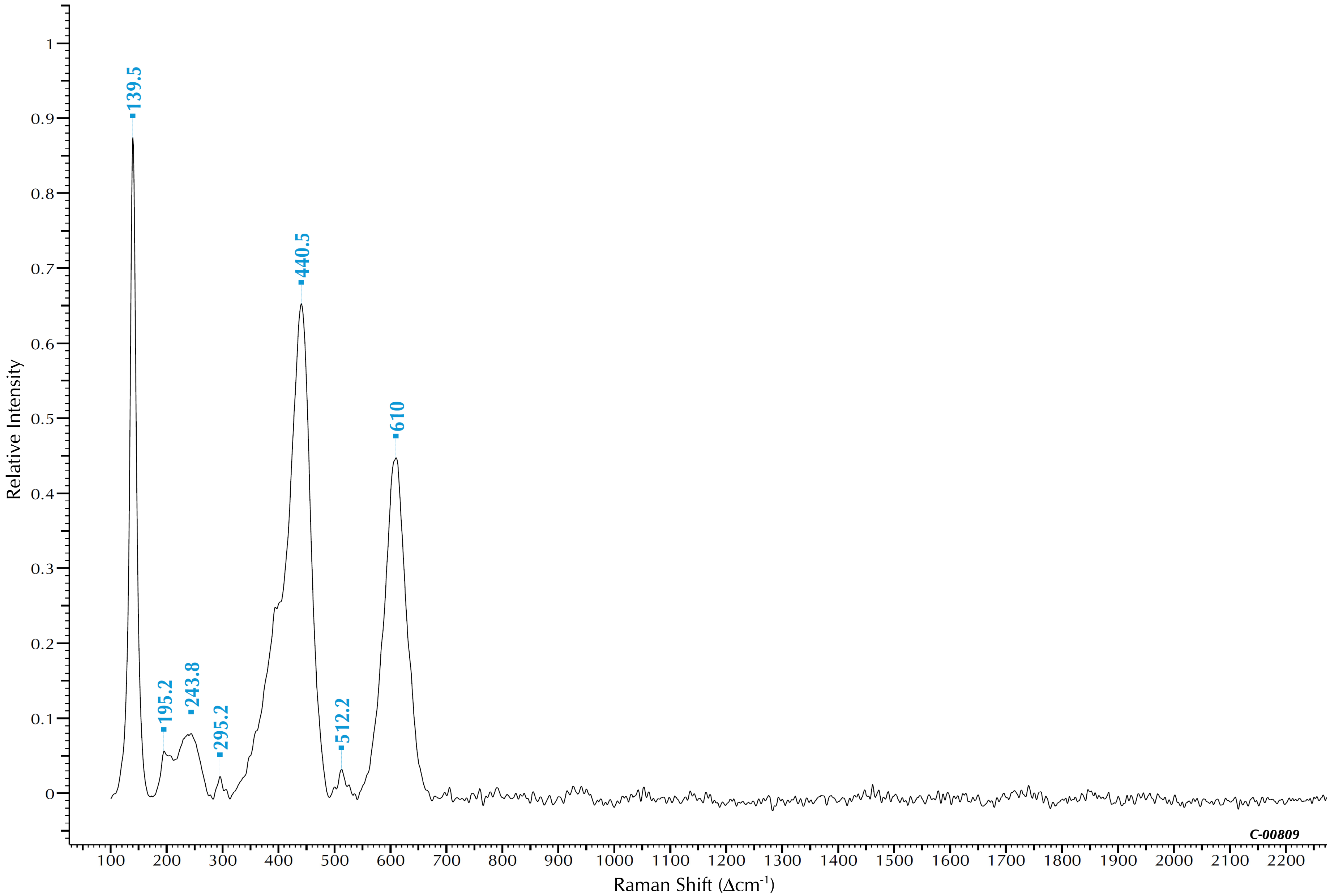
Chemical Category: Inorganic - Hydroxide
Constitution Number: 77491 77492 ; 77499

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Brown 7



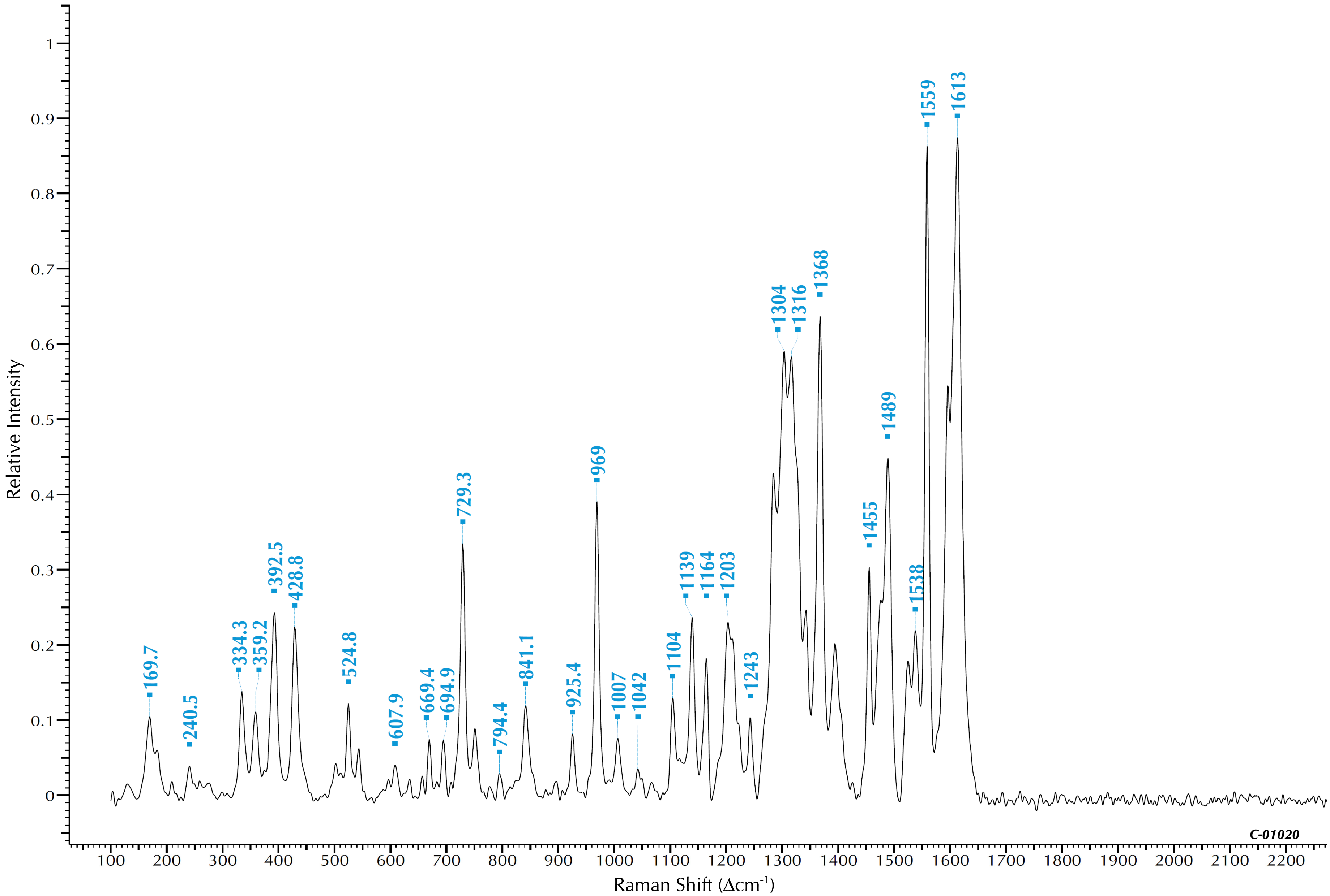
Chemical Category: Inorganic - Oxide
Constitution Number: 77491 77492

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Brown 23



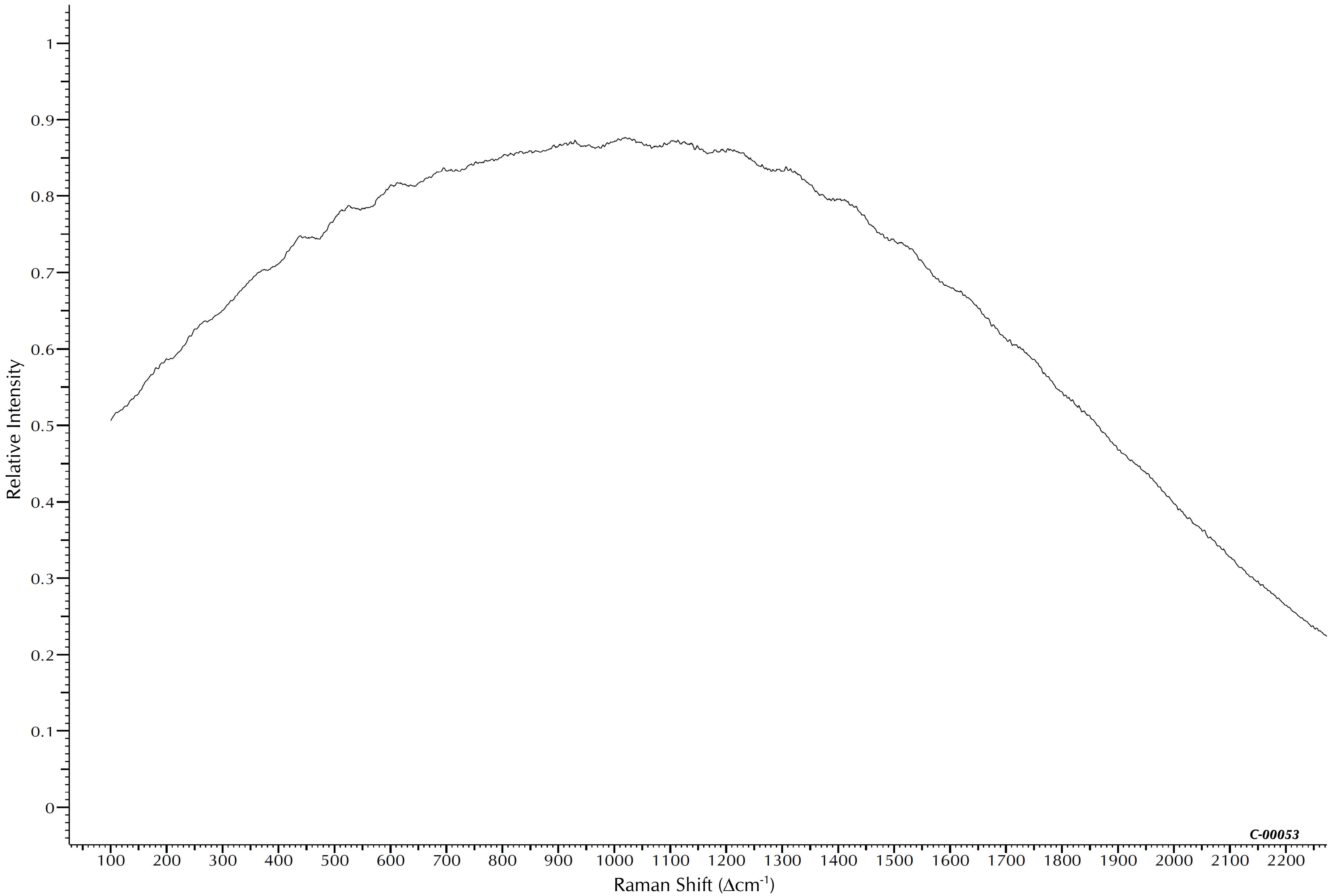
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20060

Bleaching Time (s): 60
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Brown 24



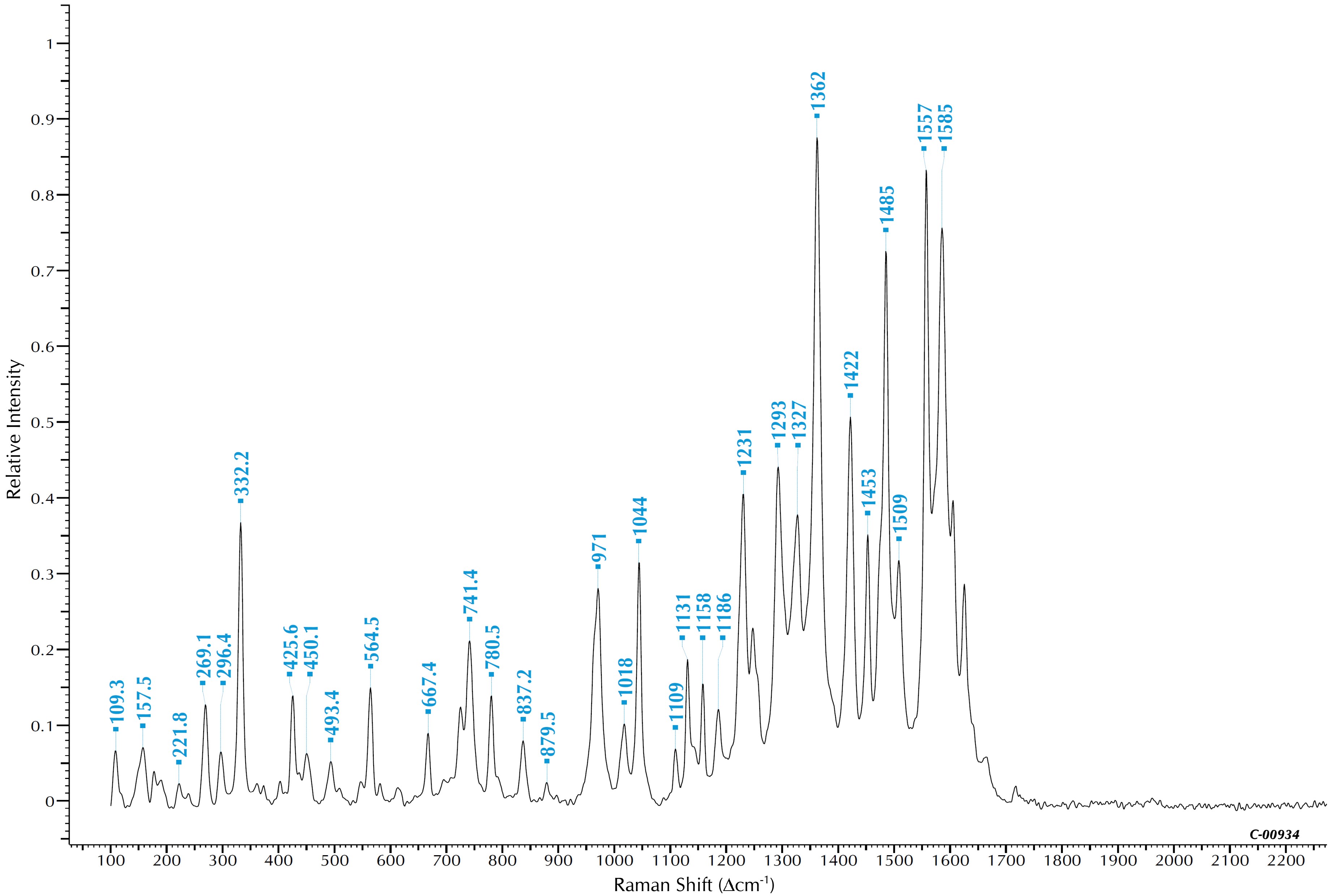
Chemical Category: Inorganic - Oxide
Constitution Number: 77310

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Brown 25



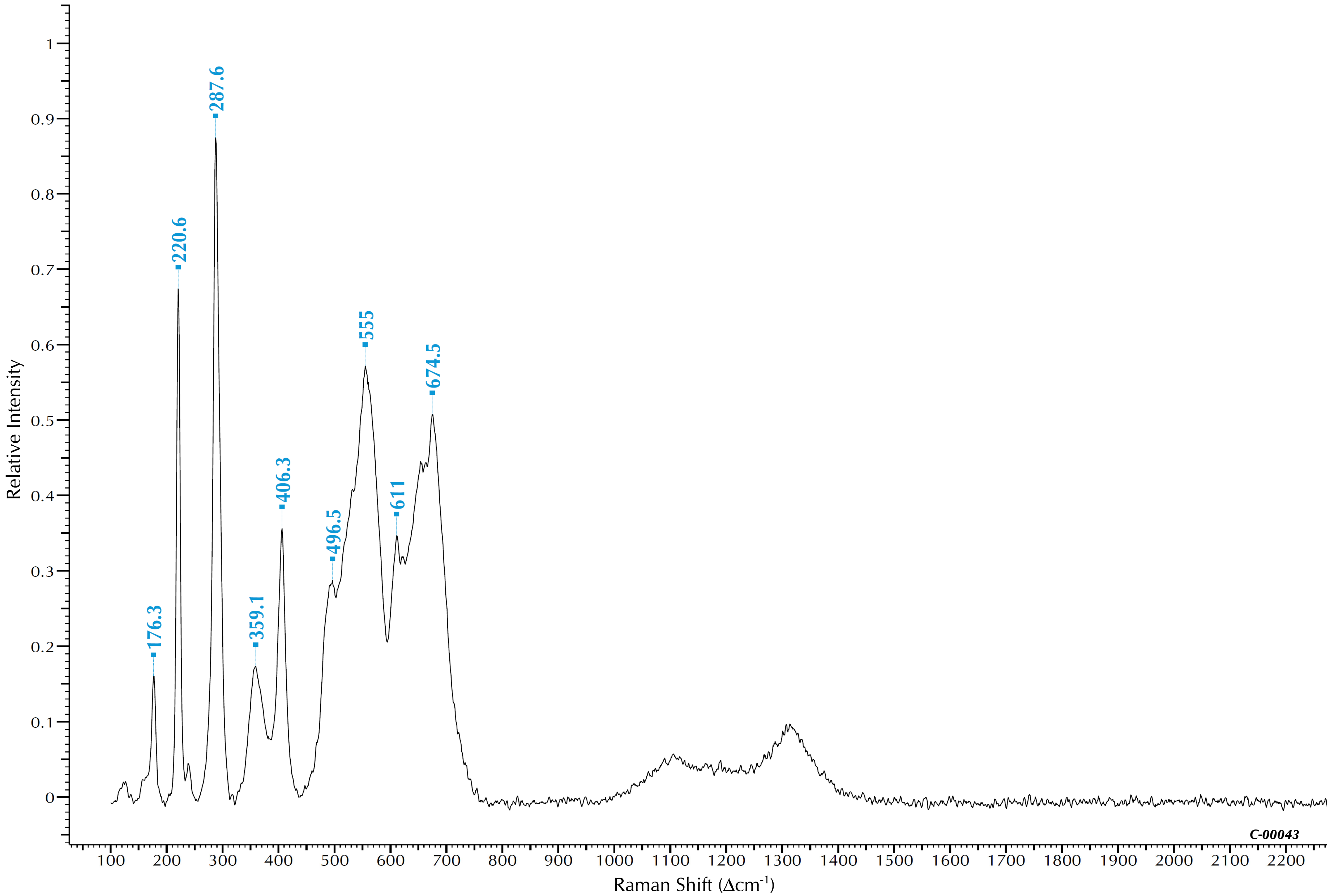
Chemical Category: Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)
Constitution Number: 12510

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Brown 31



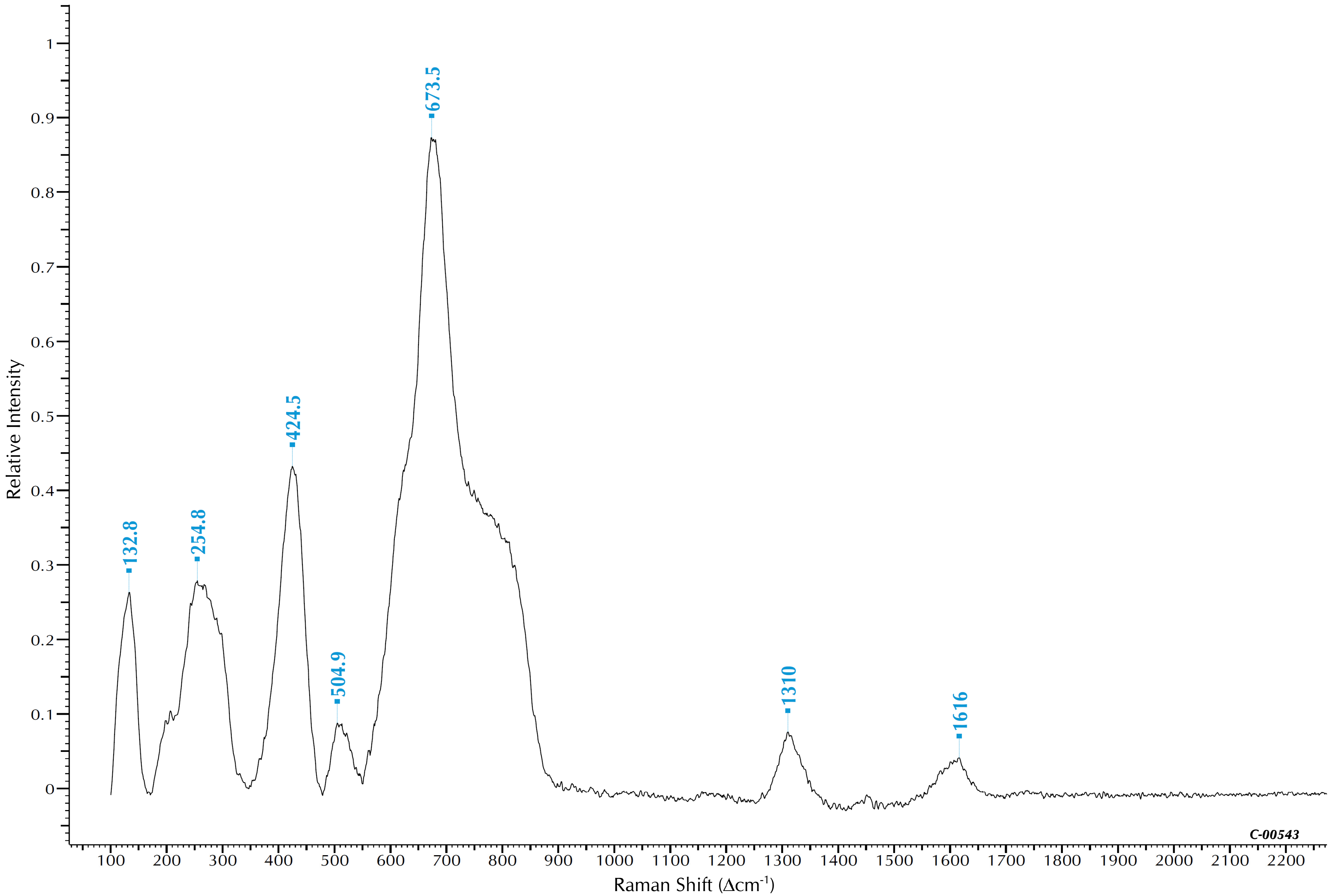
Chemical Category: Inorganic - Oxide
Constitution Number: 77496

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Brown 40



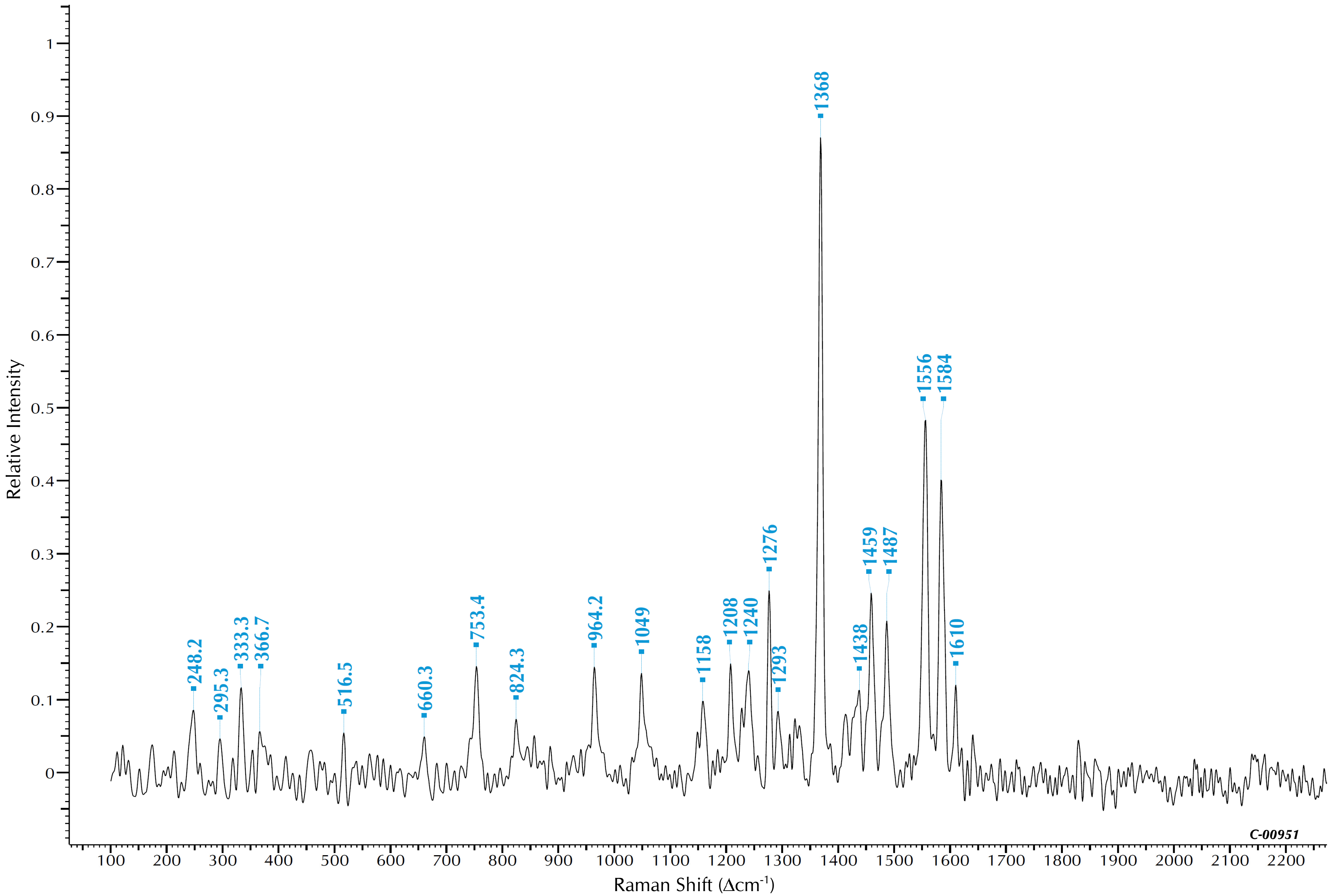
Chemical Category: Inorganic - Titanate
Constitution Number: 77897

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 5

Microtrace LLC

C.I. Pigment Brown 41



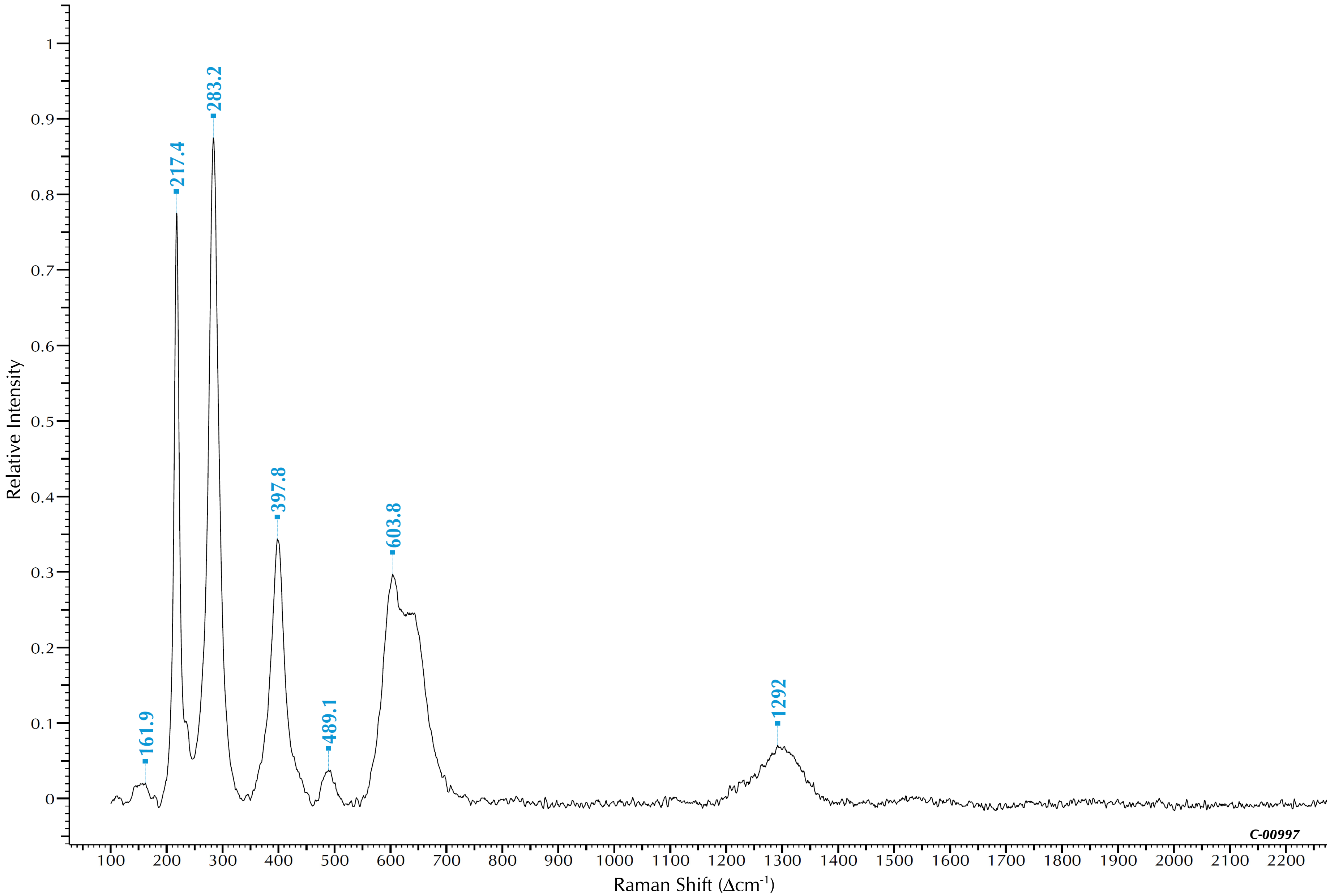
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: Confidentia

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Brown 43



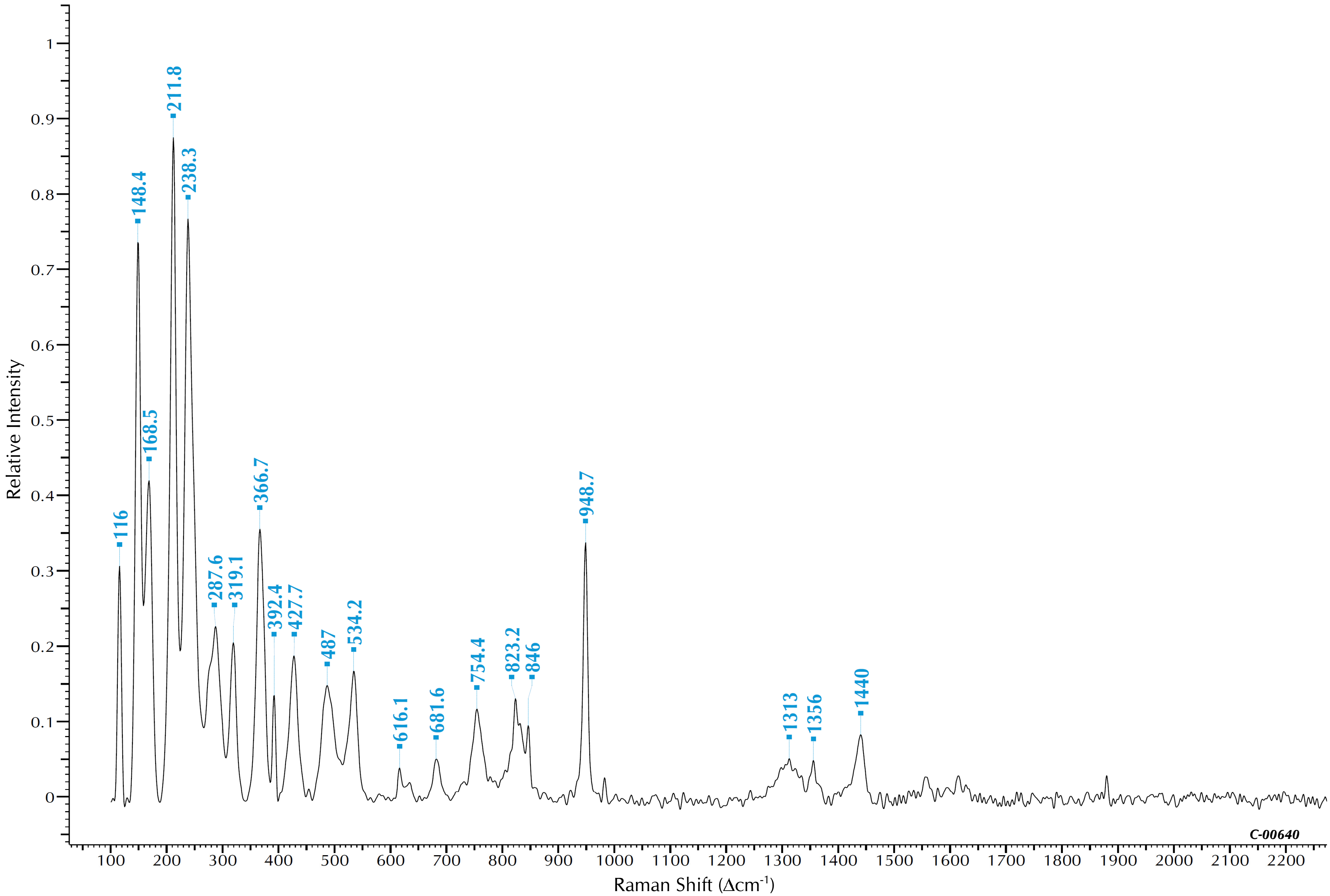
Chemical Category: Inorganic - Oxide
Constitution Number: 77536

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Green 1



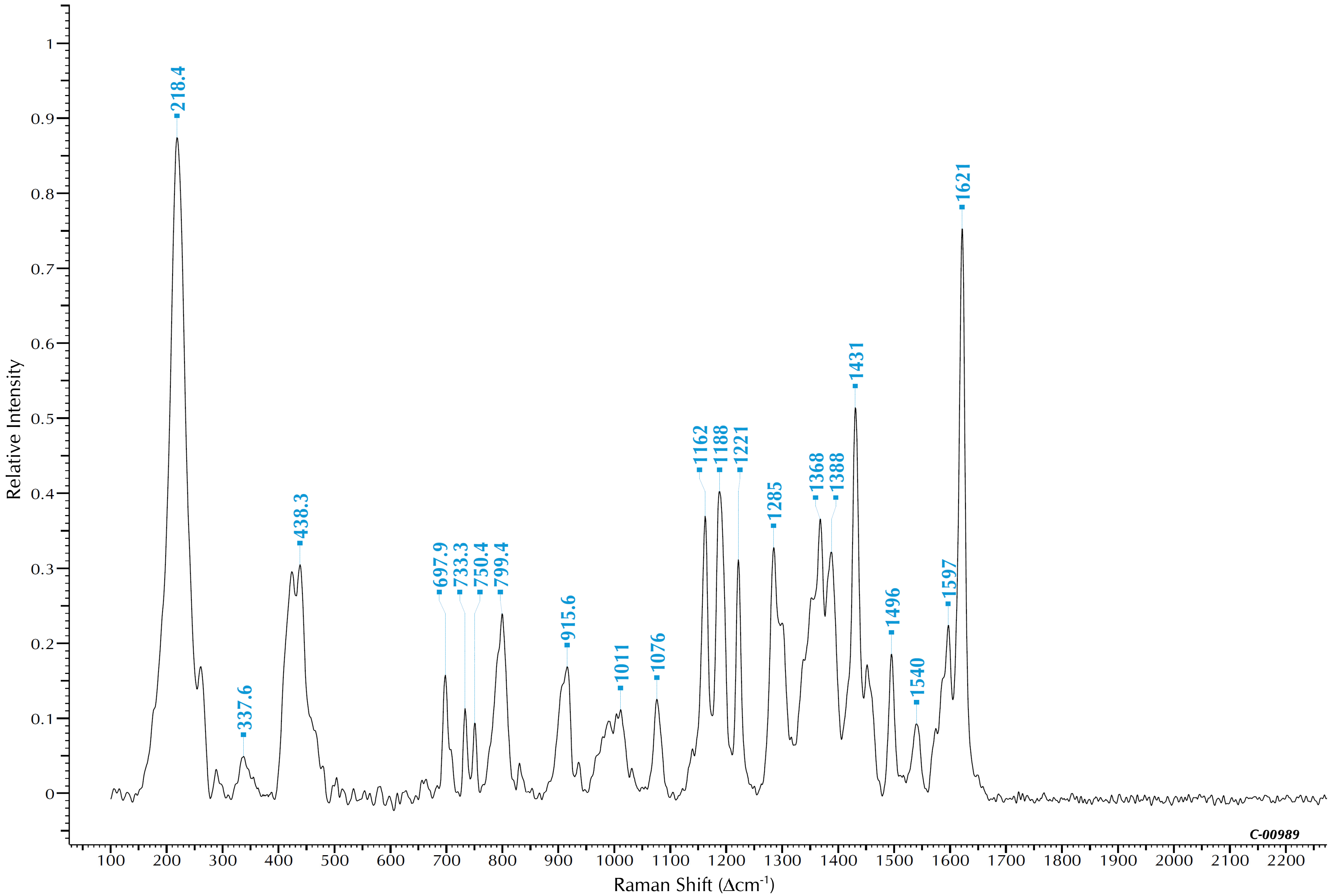
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42040:1

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 4

Microtrace LLC

C.I. Pigment Green 2



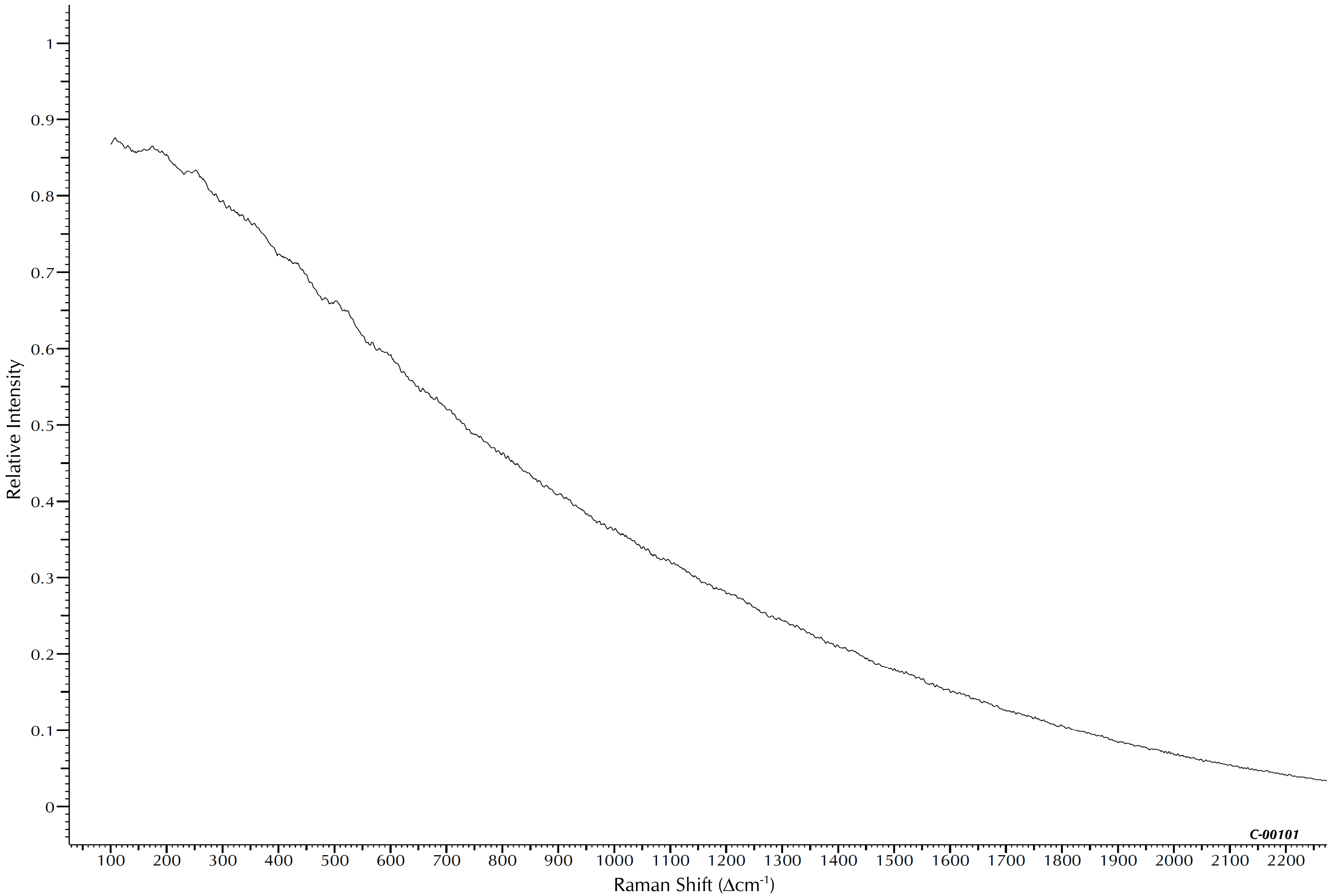
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42040:1 49005:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Green 4



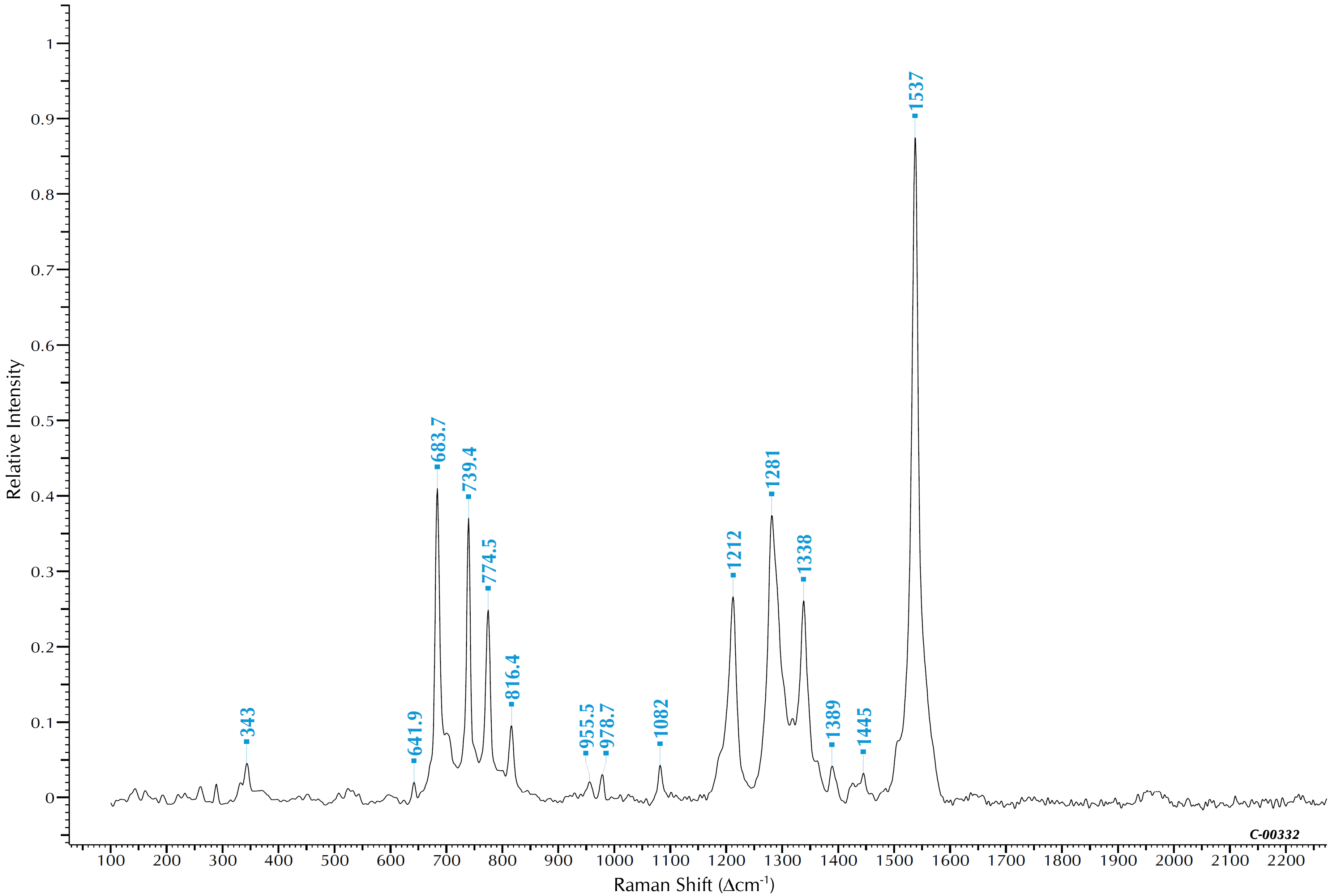
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42000:2

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.00485
Quality Index 3

Microtrace LLC

C.I. Pigment Green 7



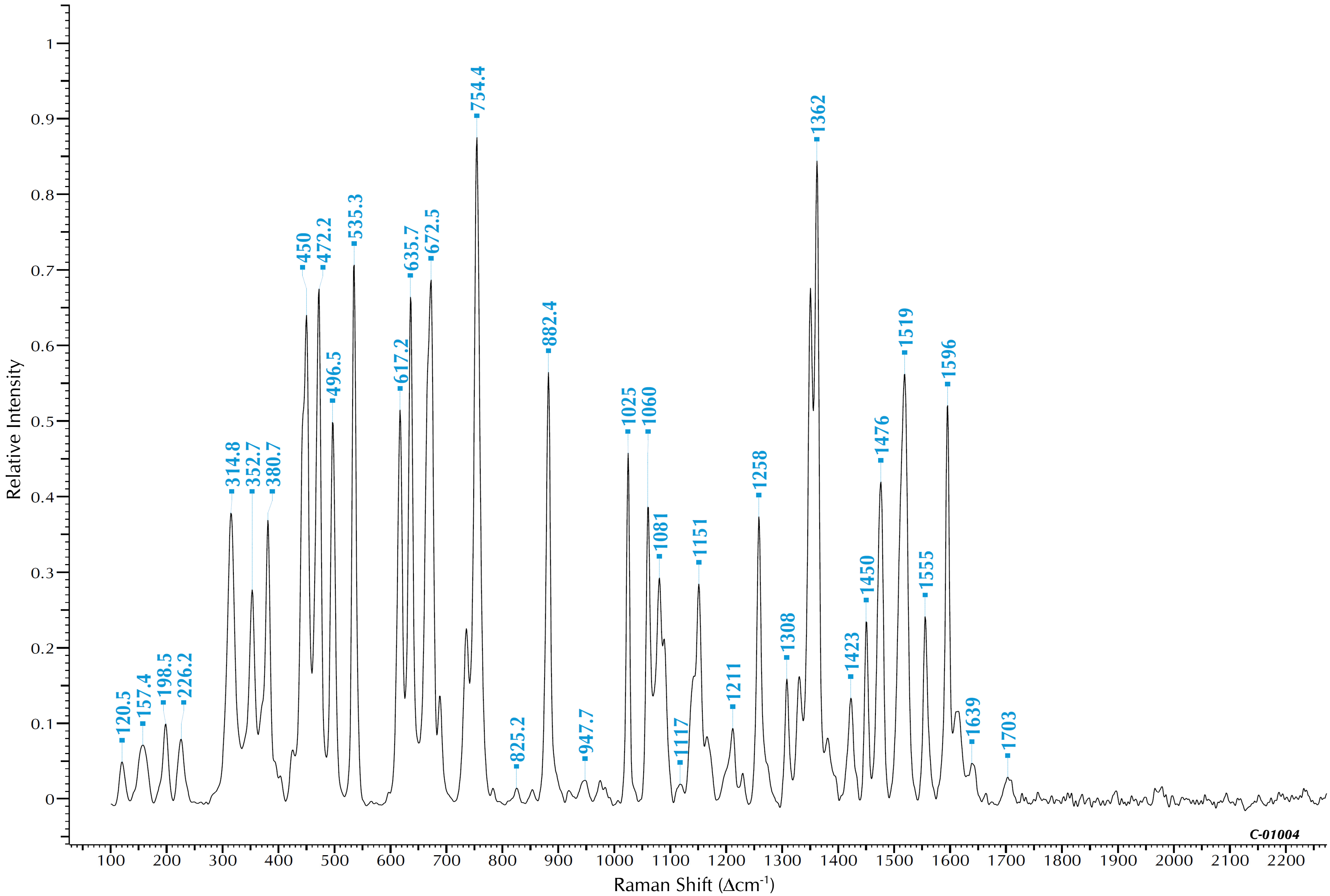
Chemical Category: Organic - Polycyclic - Phthalocyanine
Constitution Number: 74260

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Green 8



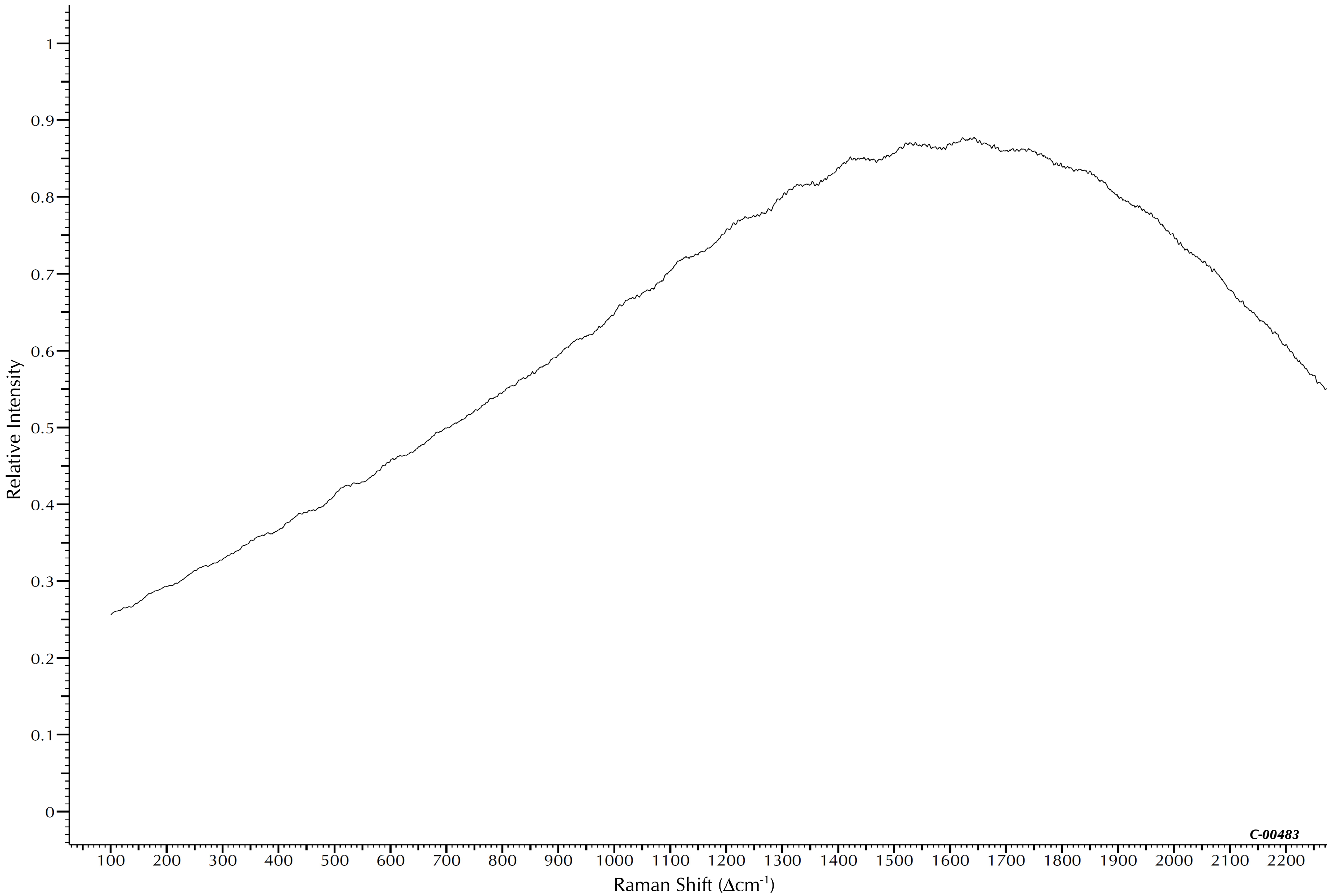
Chemical Category: Organic - Azo - Metal Complex - Azo
Constitution Number: 10006

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Green 14



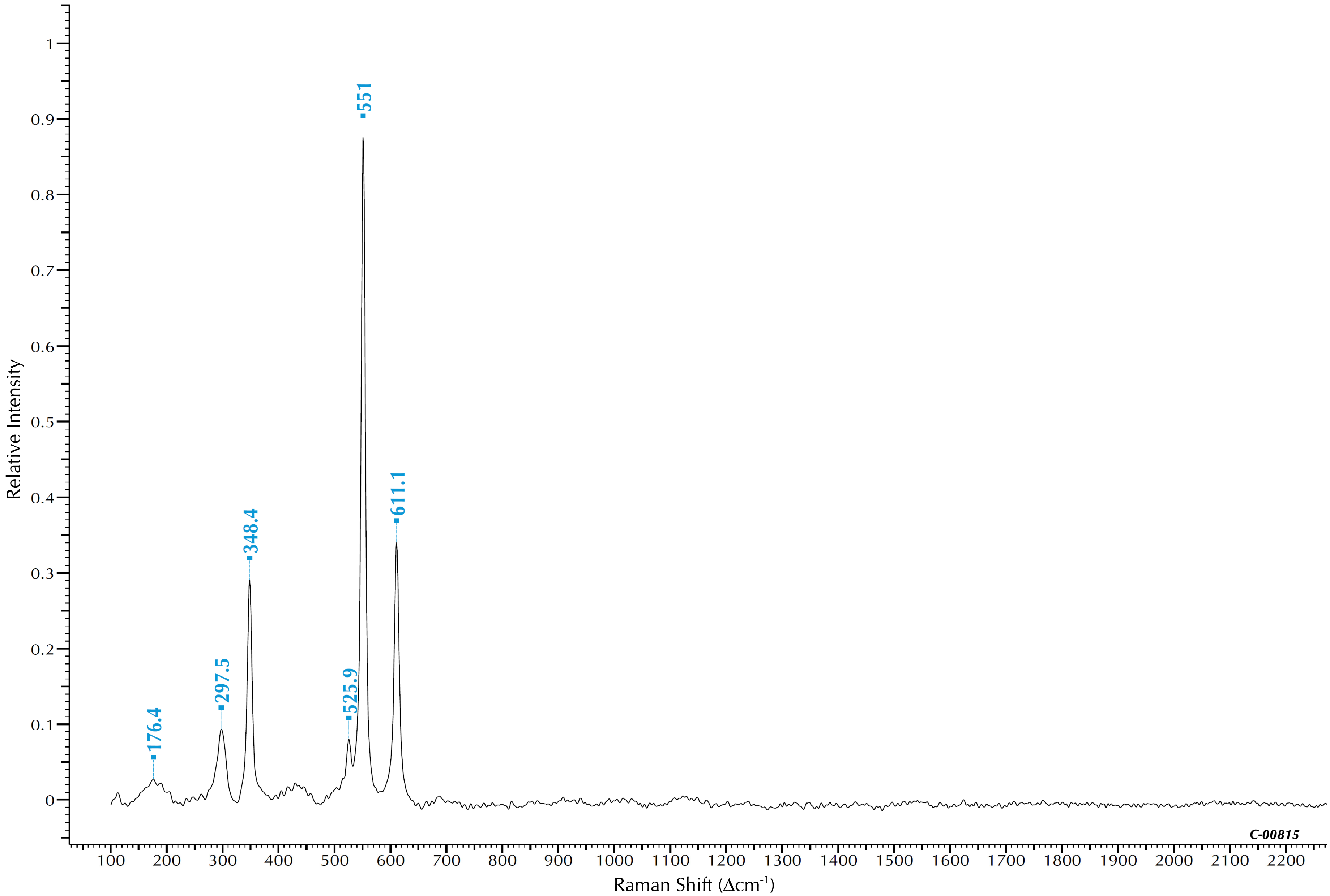
Chemical Category: Inorganic - Sulfide
Constitution Number: 77199 77346

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Green 17



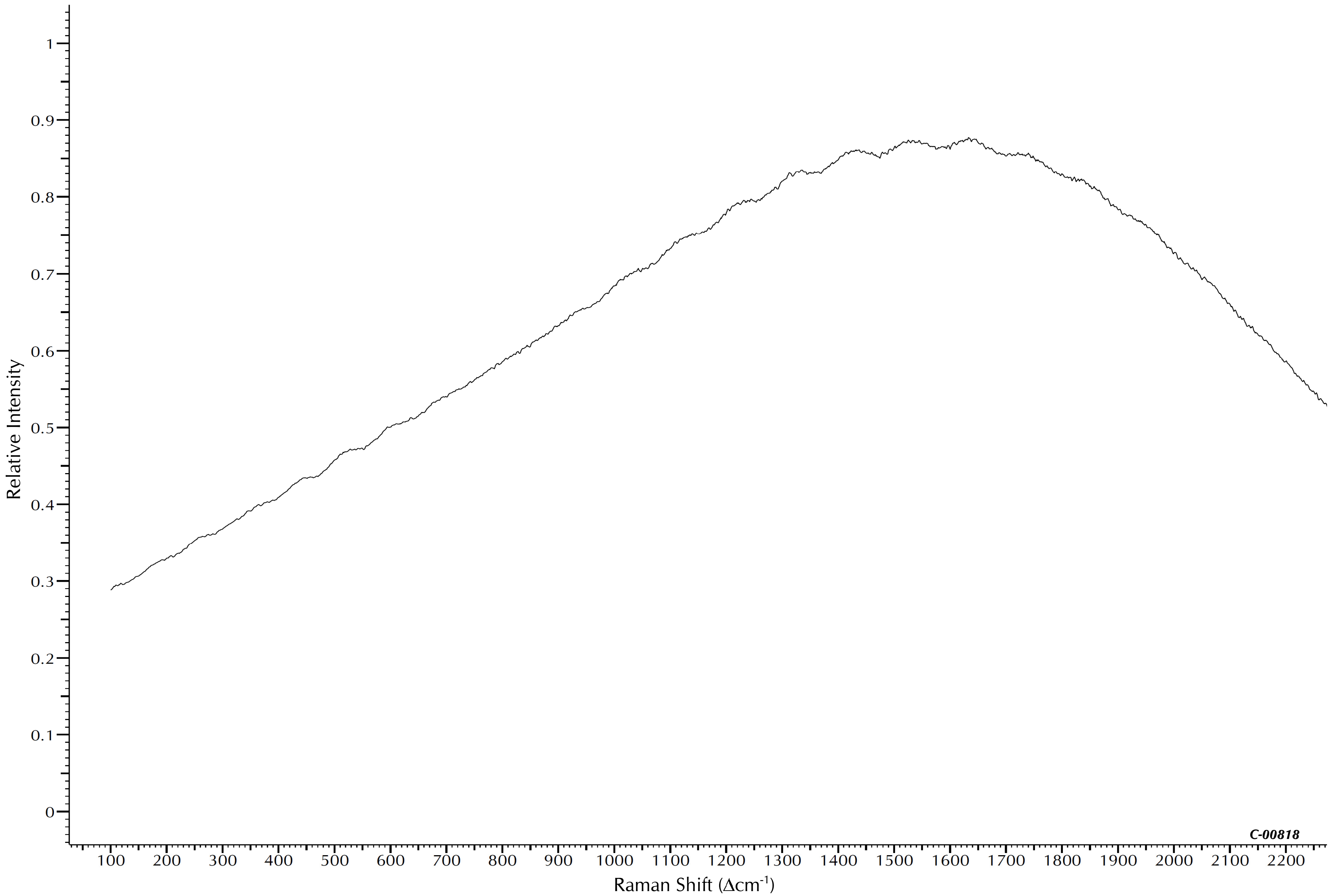
Chemical Category: Inorganic - Oxide
Constitution Number: 77288

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Green 18



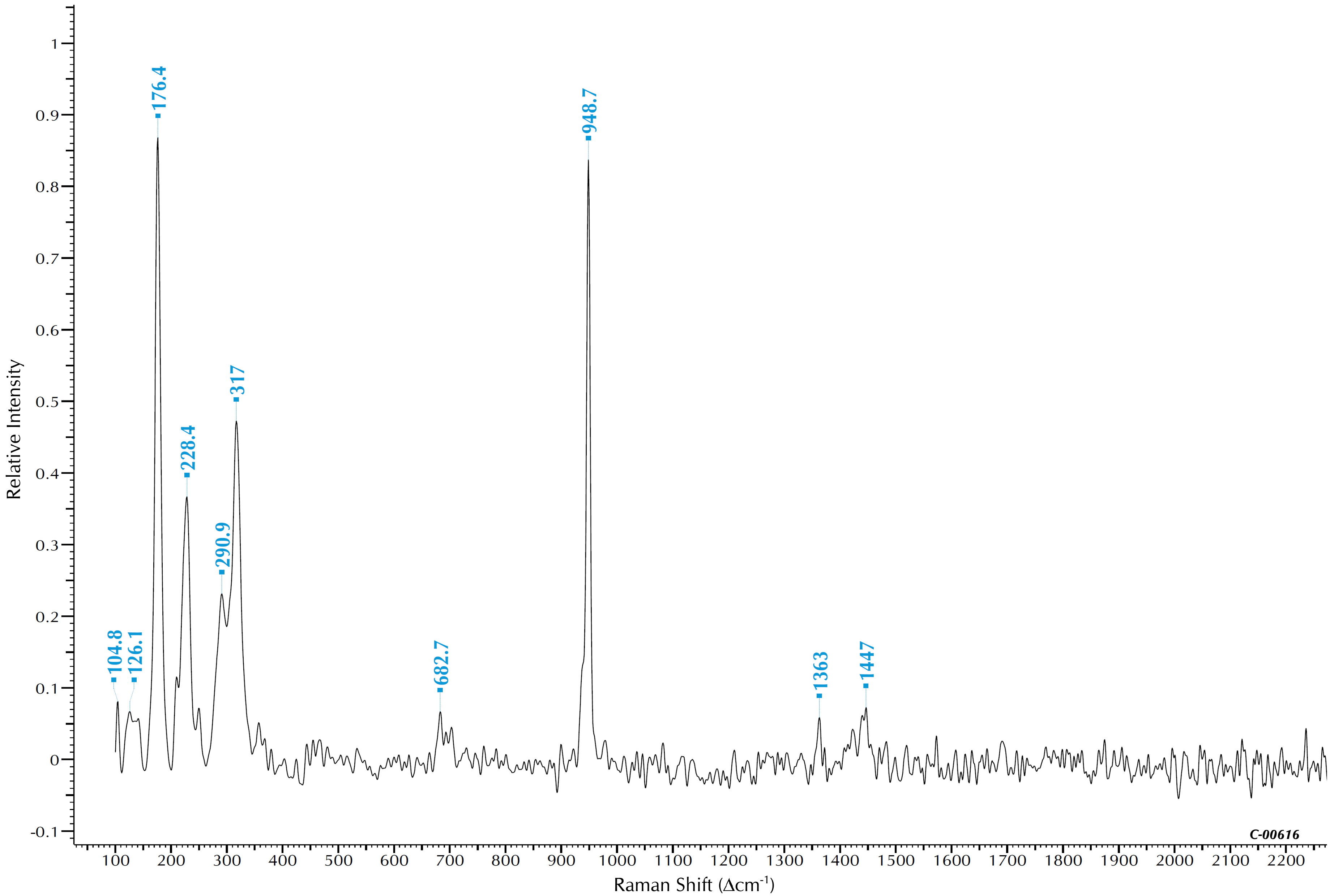
Chemical Category: Inorganic - Oxide
Constitution Number: 77289

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Green 20



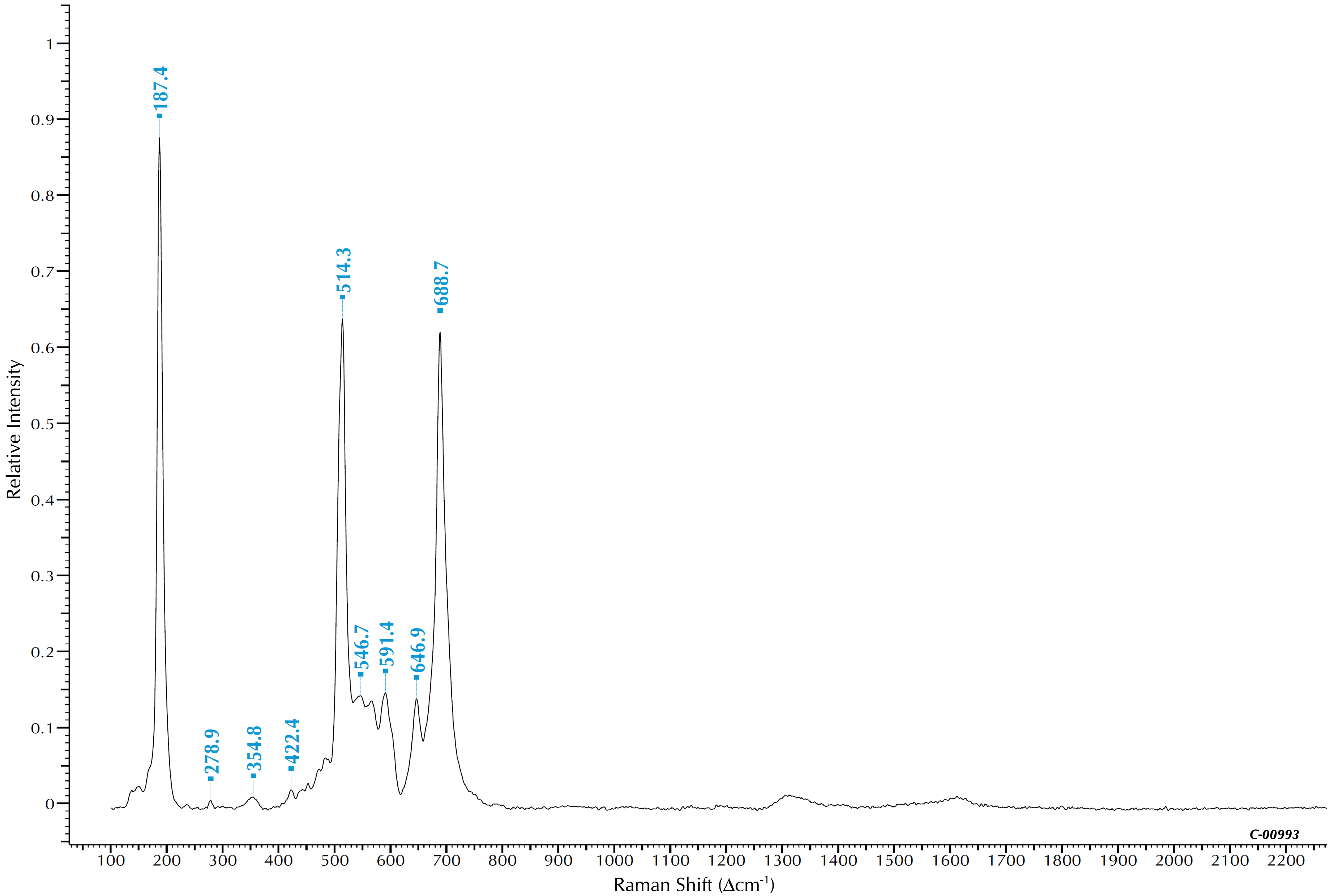
Chemical Category: Inorganic - Hydroxide
Constitution Number: 77408

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 10

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 5

Microtrace LLC

C.I. Pigment Green 26



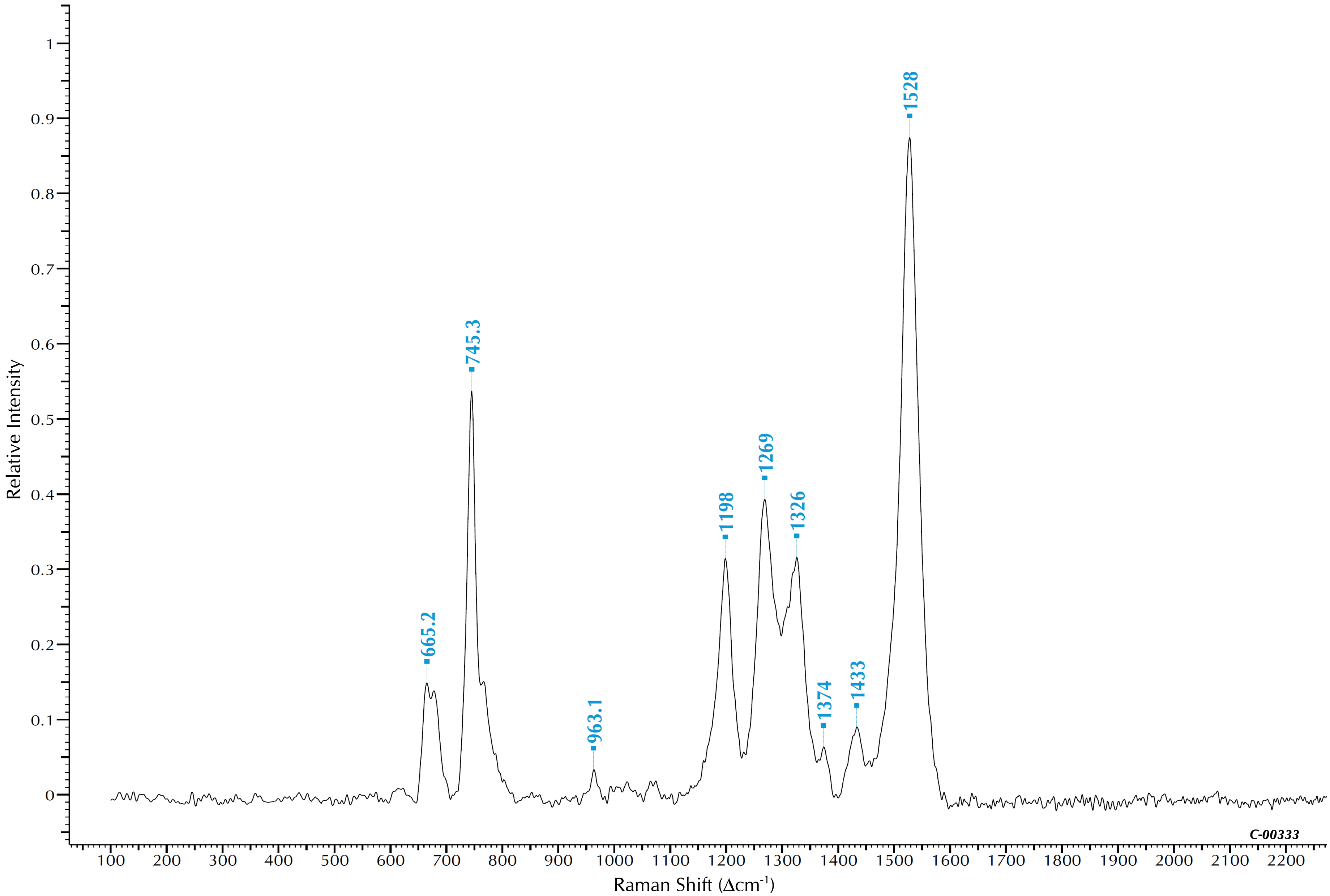
Chemical Category: Inorganic - Oxide
Constitution Number: 77344

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Green 36



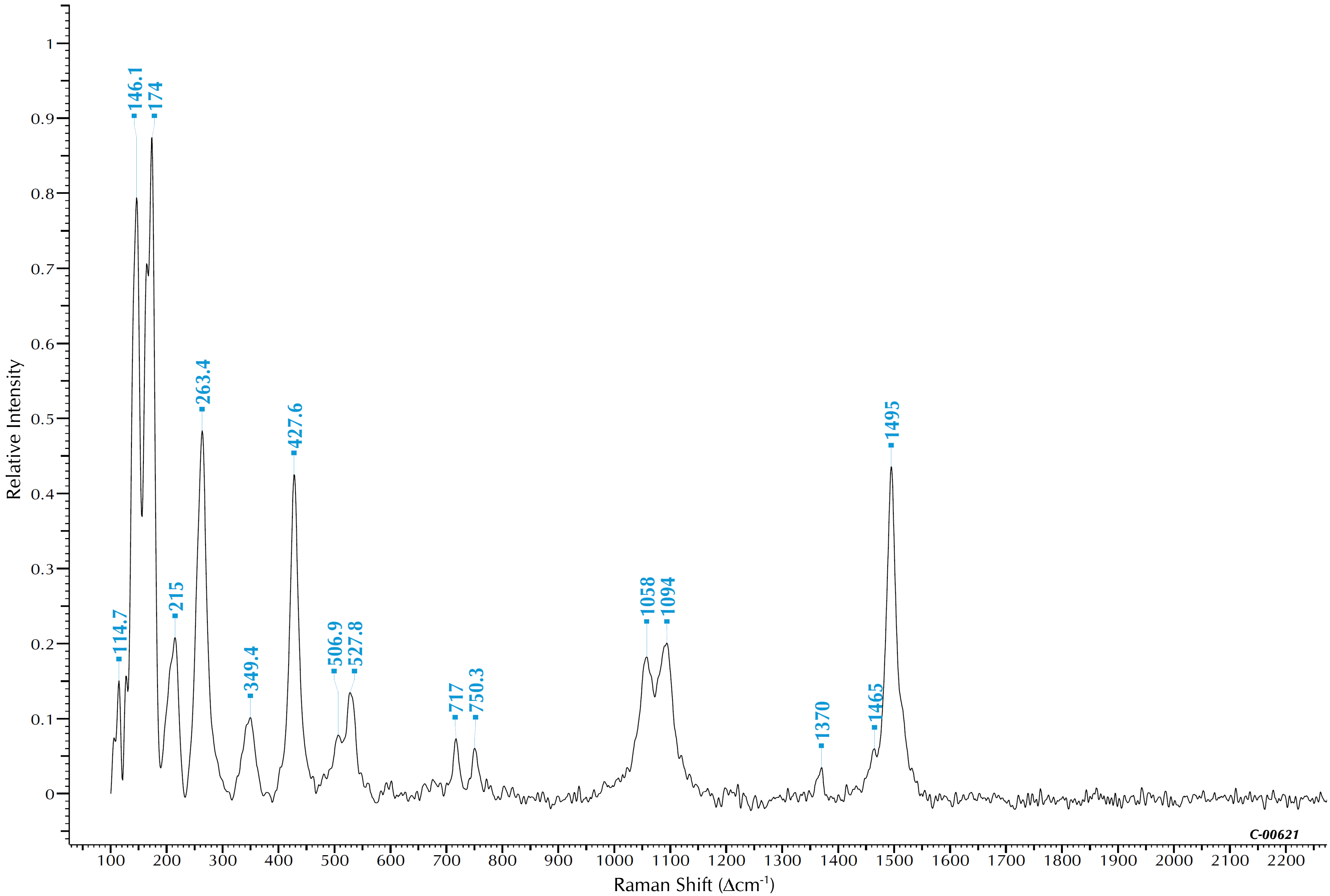
Chemical Category: Organic - Polycyclic - Phthalocyanine
Constitution Number: 74265

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Green 39



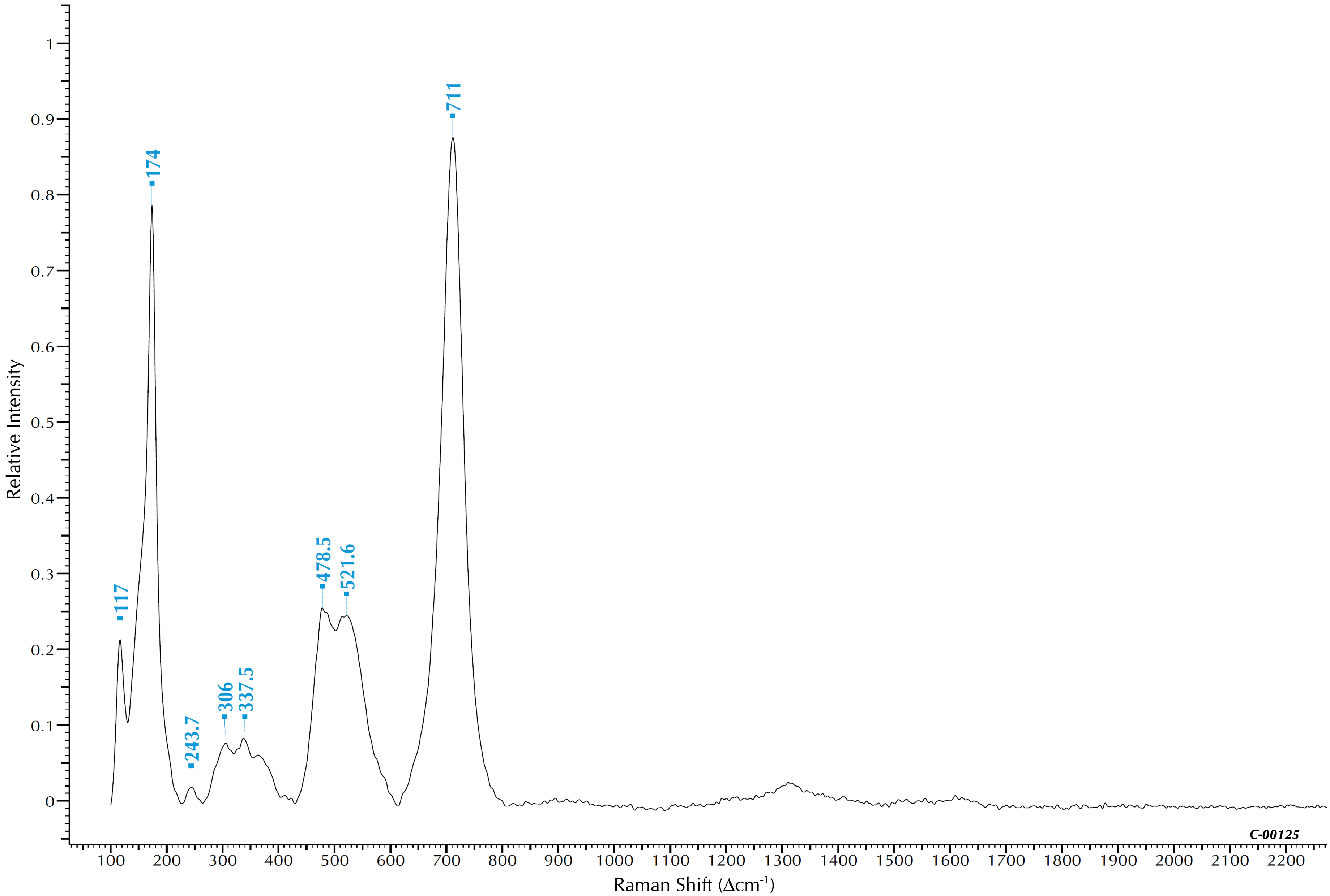
Chemical Category: Inorganic - Hydroxide
Constitution Number: 77492

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 10

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Green 50



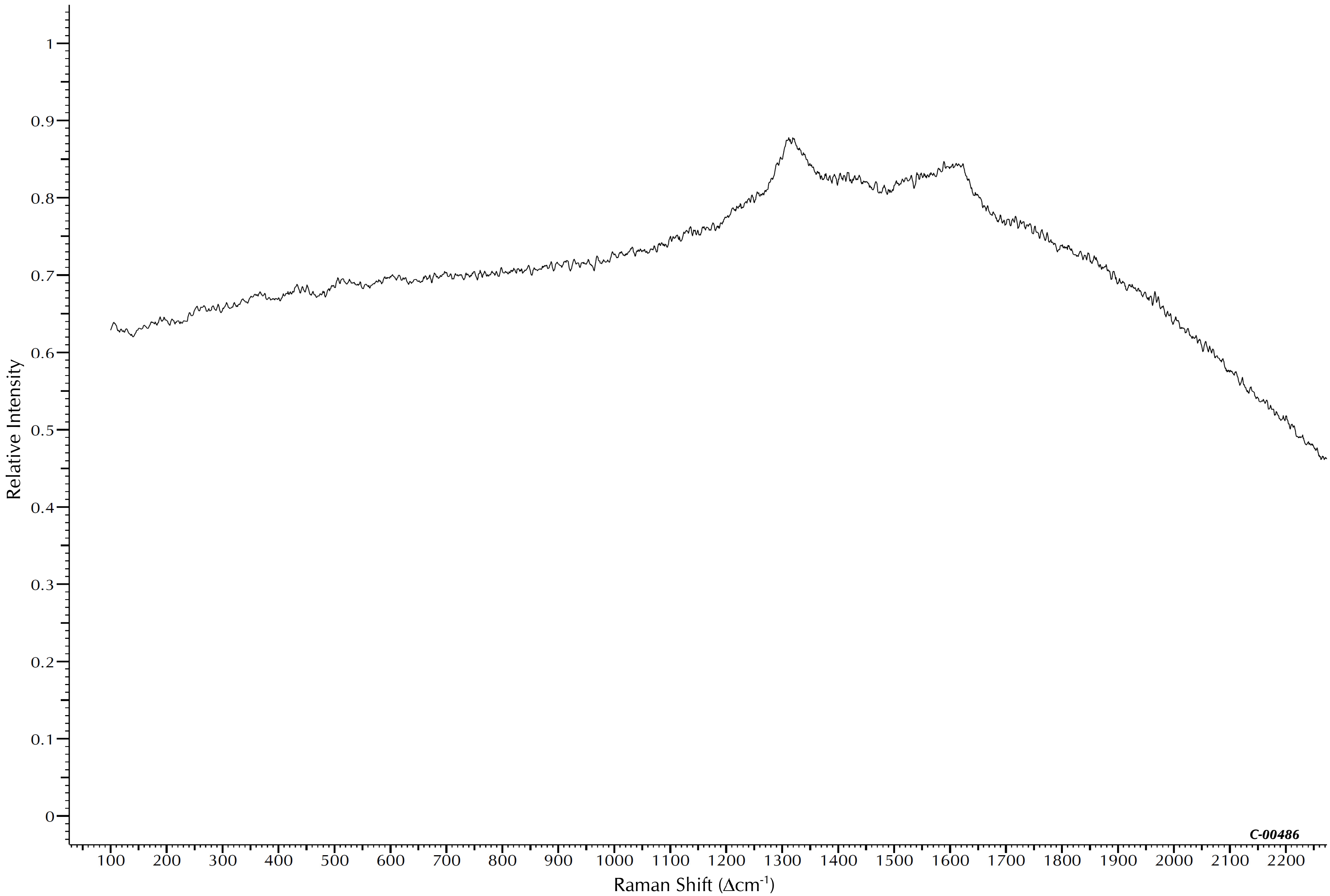
Chemical Category: Inorganic - Titanate
Constitution Number: 77377

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Metal 1



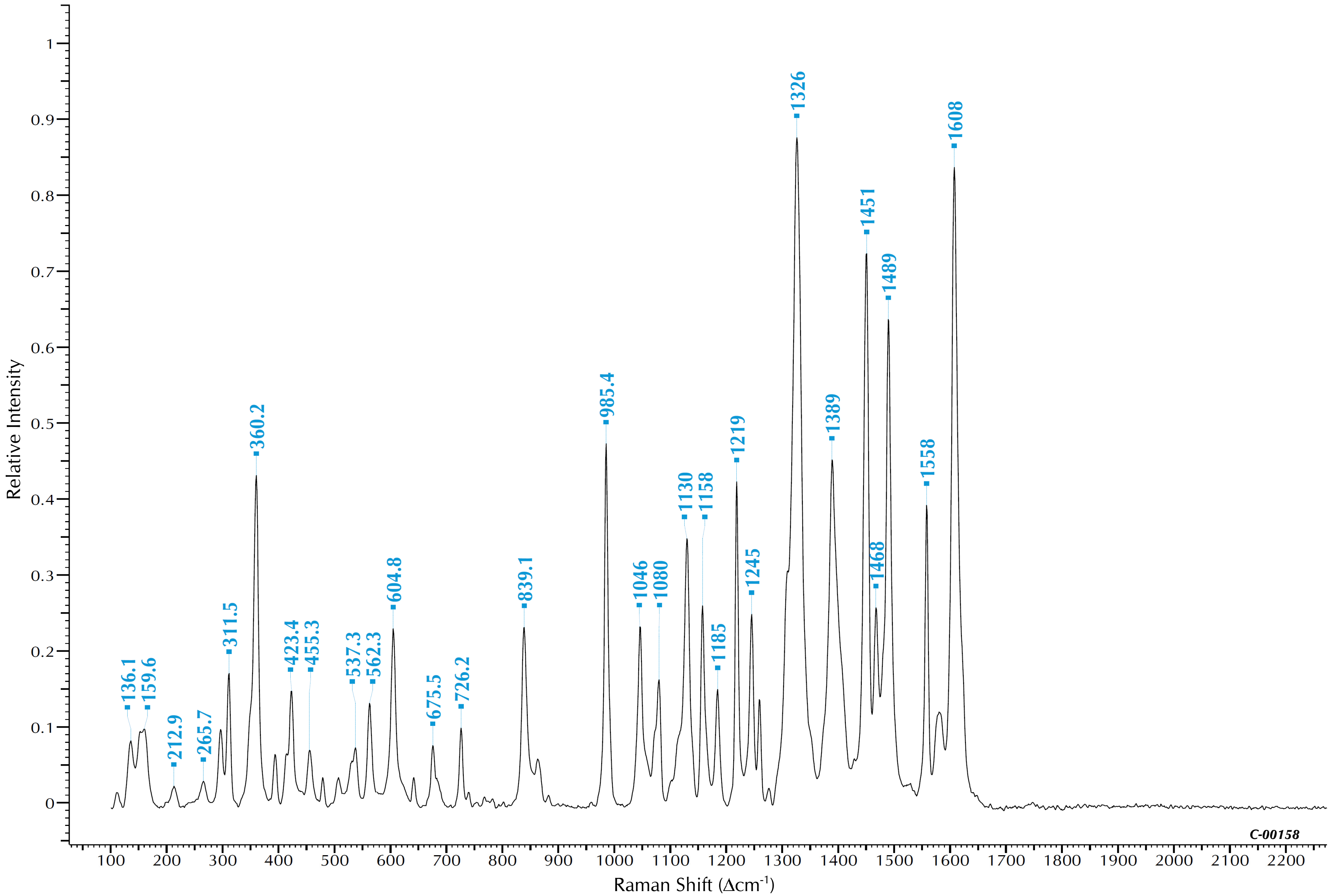
Chemical Category: Inorganic - Metal - Aluminum
Constitution Number: 77000

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 4

Microtrace LLC

C.I. Pigment Orange 2



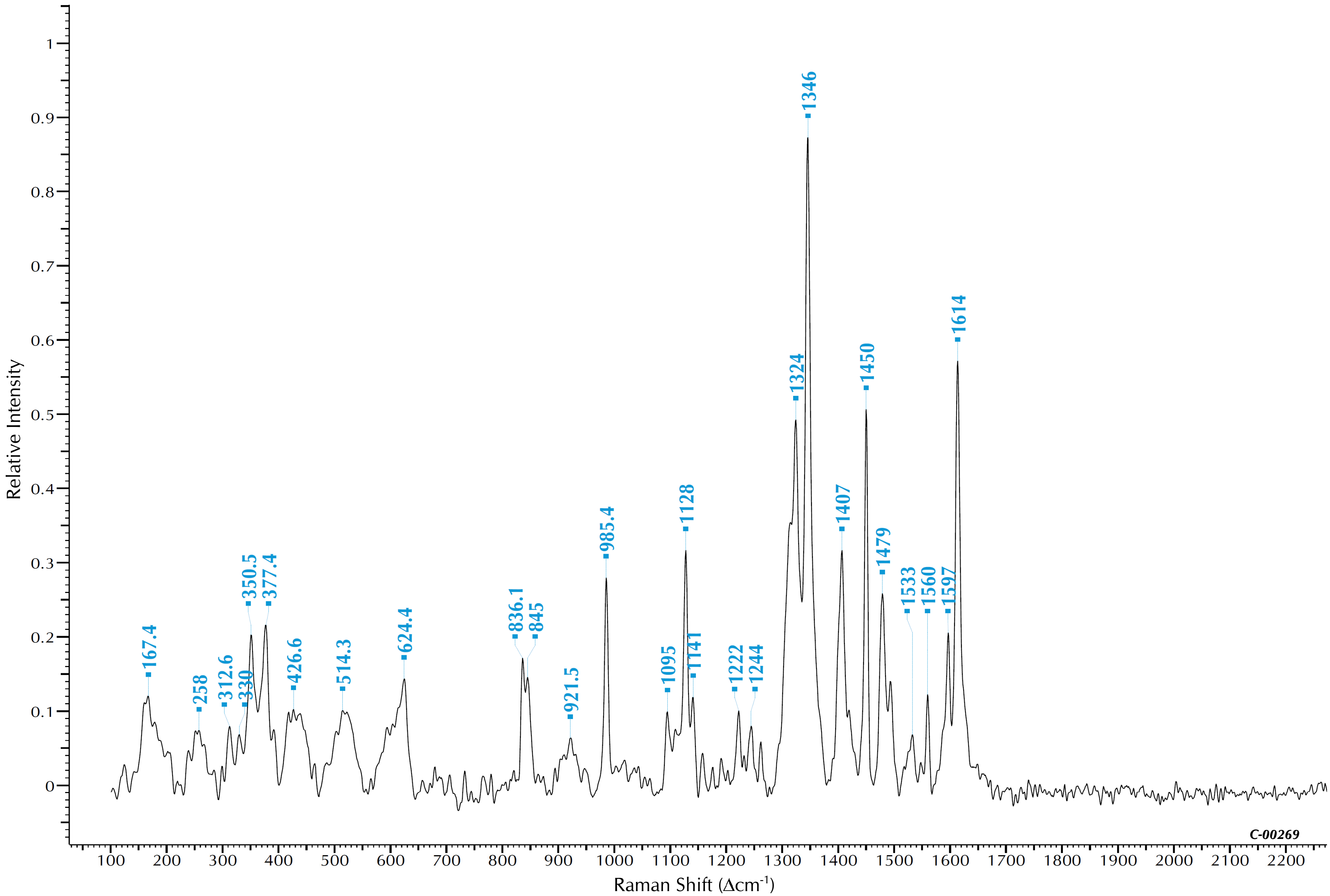
Chemical Category: Organic - Azo - Beta-Napthol
Constitution Number: 12060

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Orange 5



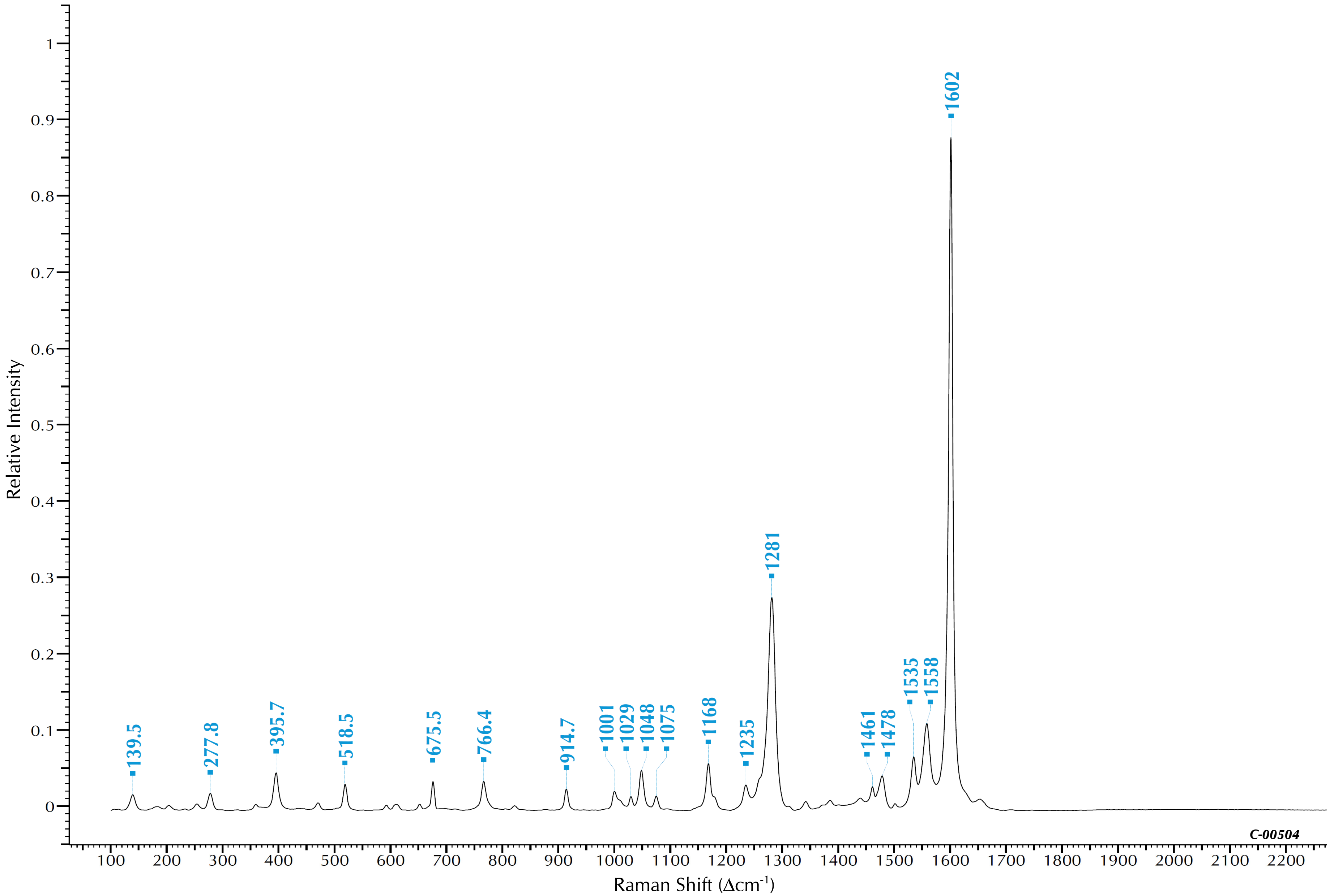
Chemical Category: Organic - Azo - Beta-Napthol
Constitution Number: 12075

Bleaching Time (s): 600
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 5

Microtrace LLC

C.I. Pigment Orange 13



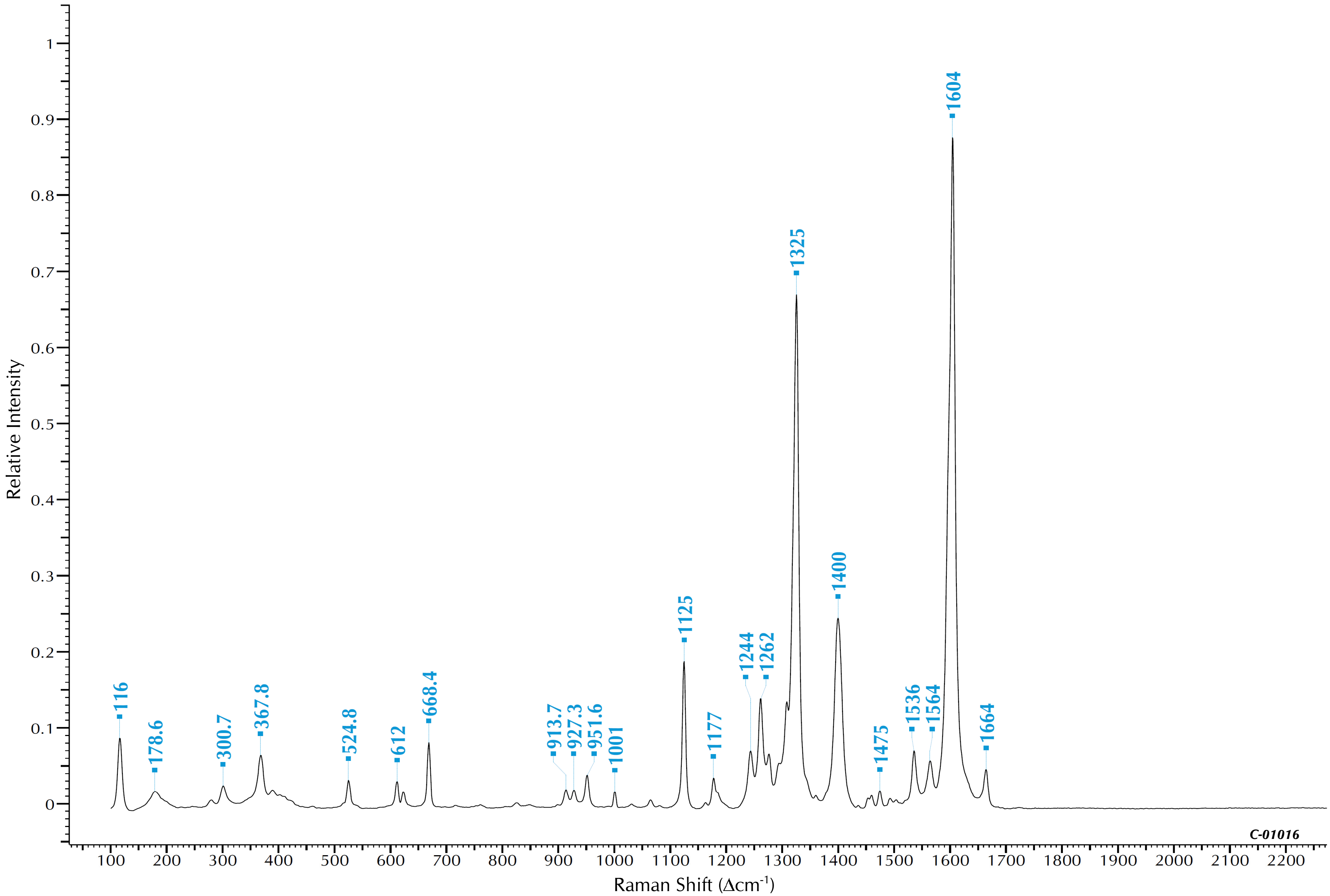
Chemical Category: Organic - Azo - Disazo - Disazopyrazolone
Constitution Number: 21110

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 5

Microtrace LLC

C.I. Pigment Orange 16



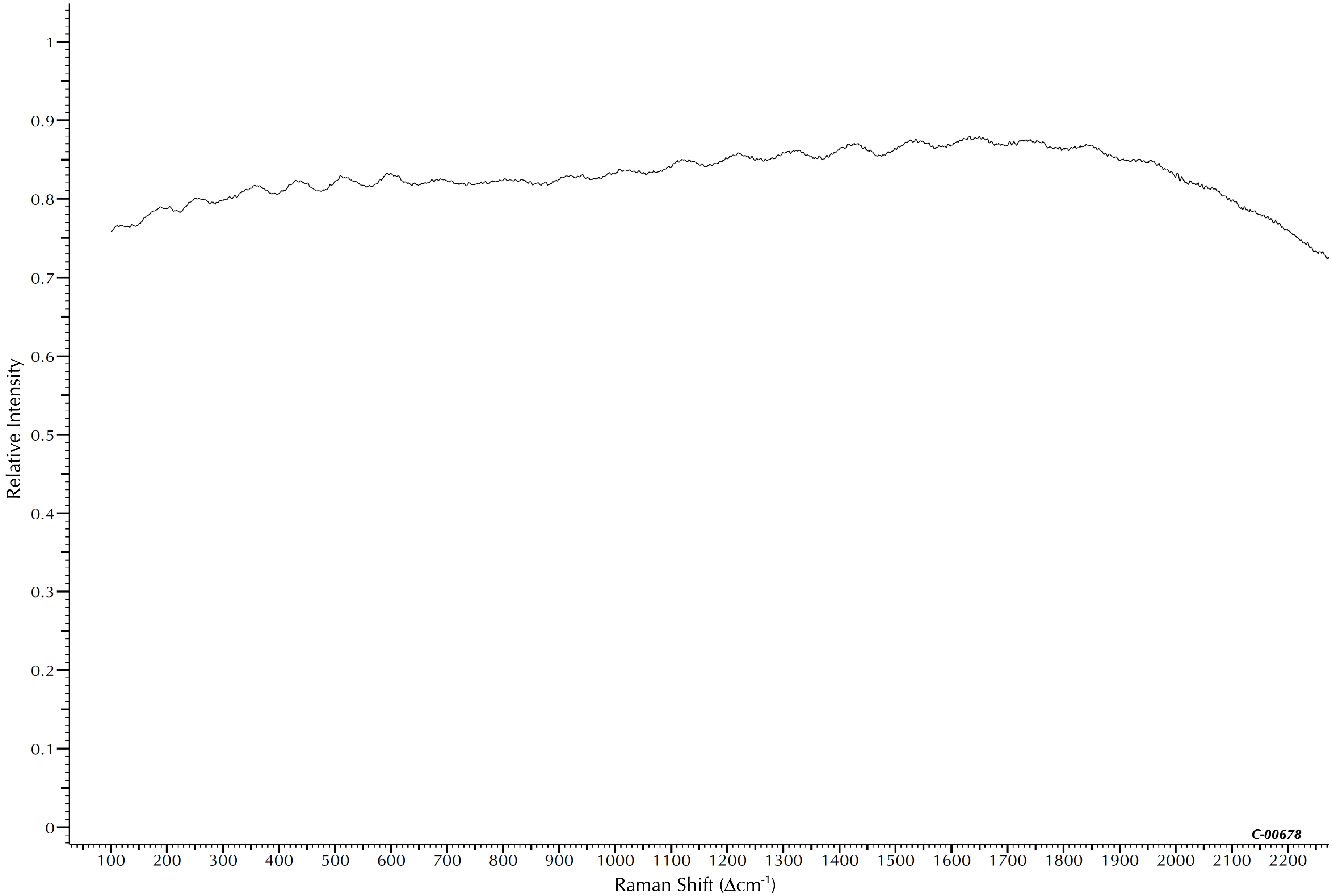
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21160

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 20



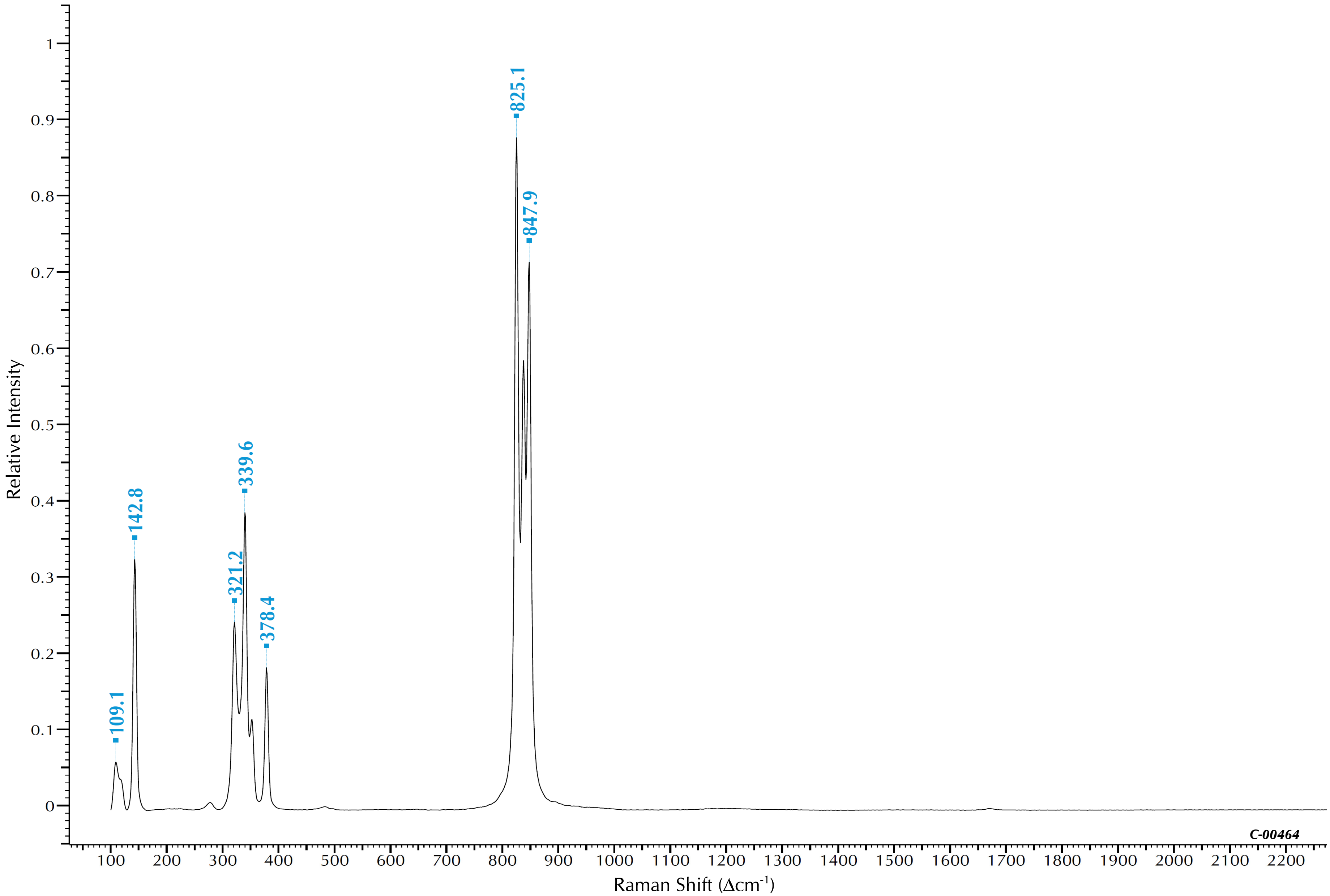
Chemical Category: Inorganic - Sulfide
Constitution Number: 77202

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 4

Microtrace LLC

C.I. Pigment Orange 21



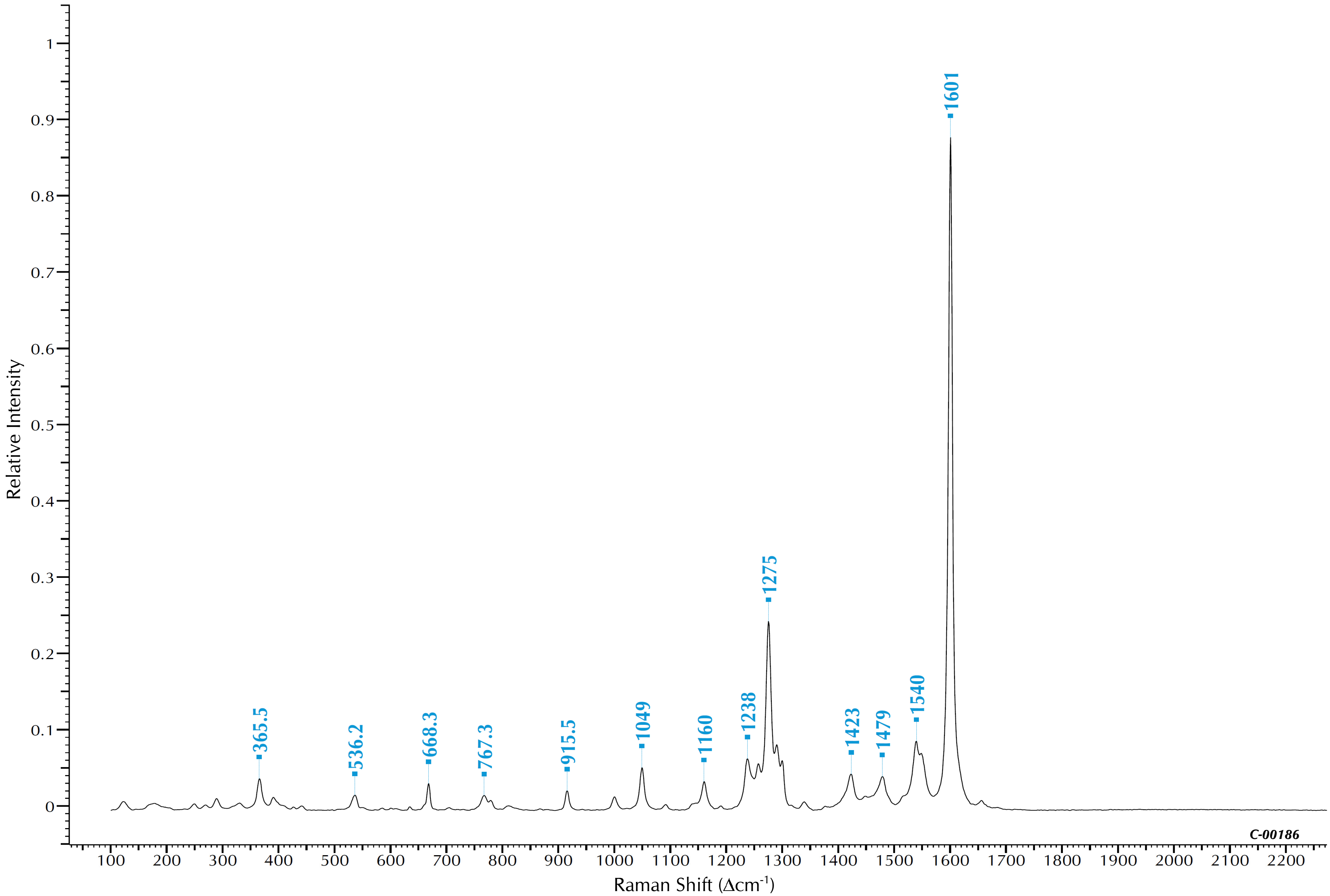
Chemical Category: Inorganic - Chromate
Constitution Number: 77601

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 4

Microtrace LLC

C.I. Pigment Orange 34



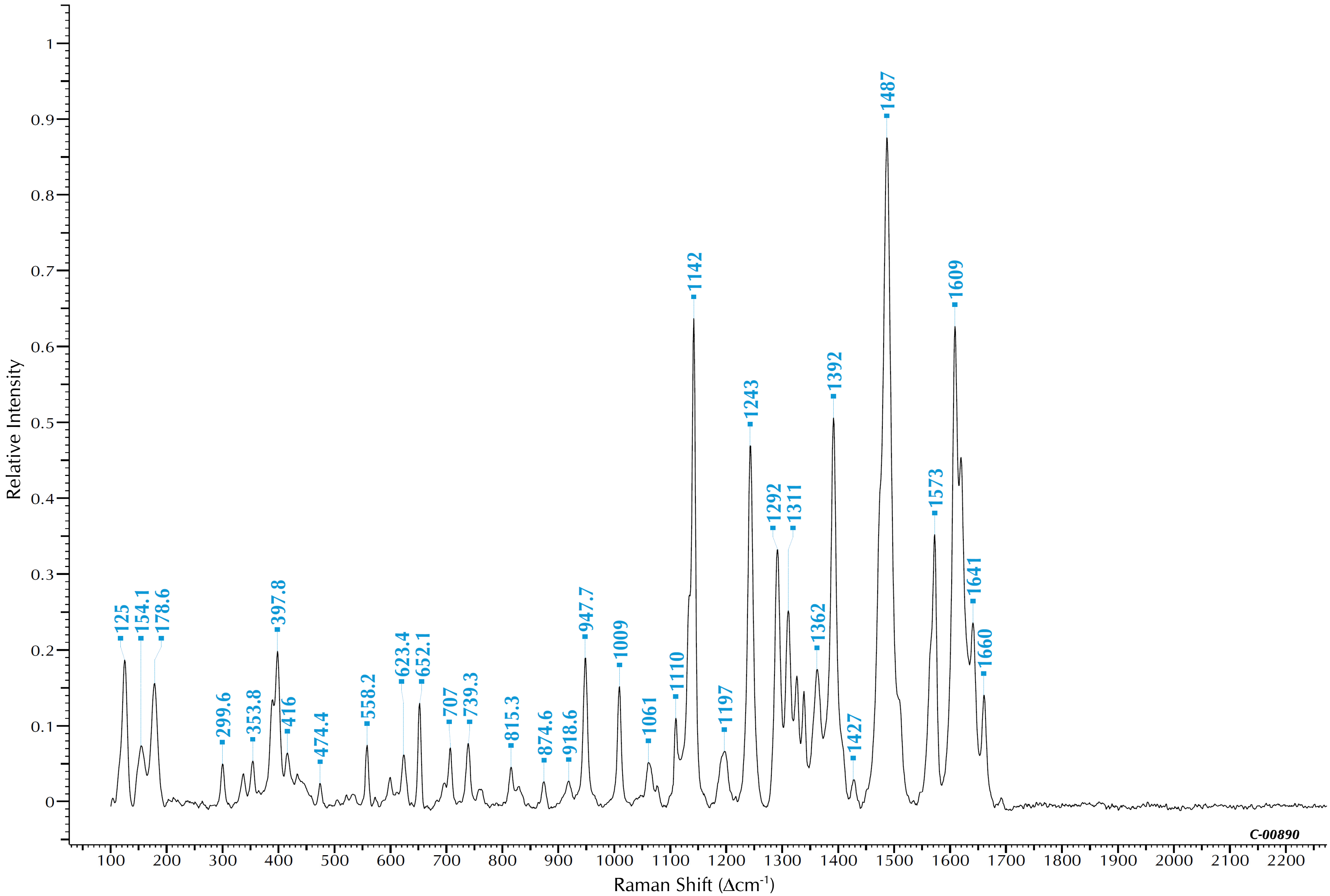
Chemical Category: Organic - Azo - Disazo - Disazopyrazolone
Constitution Number: 21115

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Orange 36



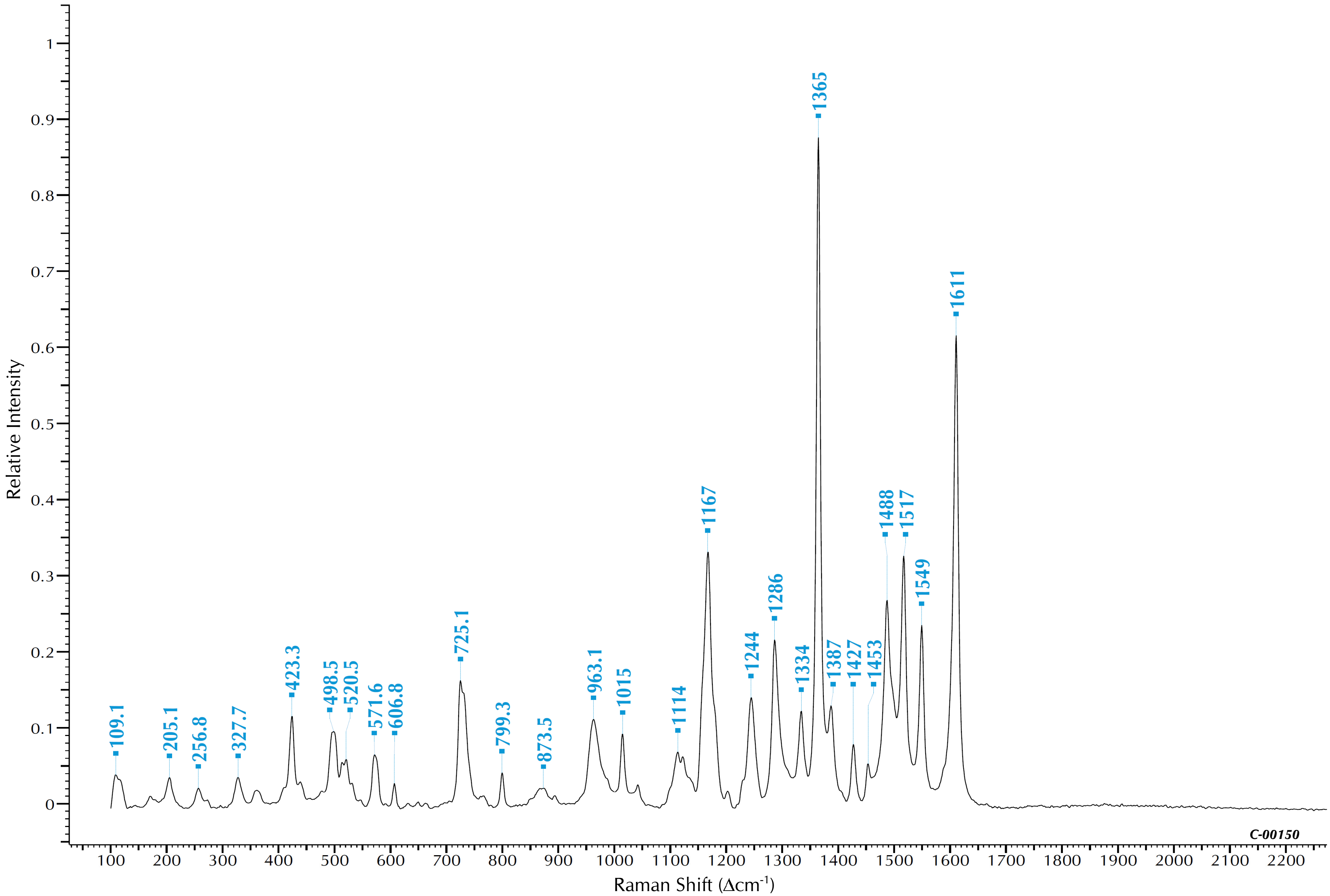
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 11780

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 2

Microtrace LLC

C.I. Pigment Orange 38



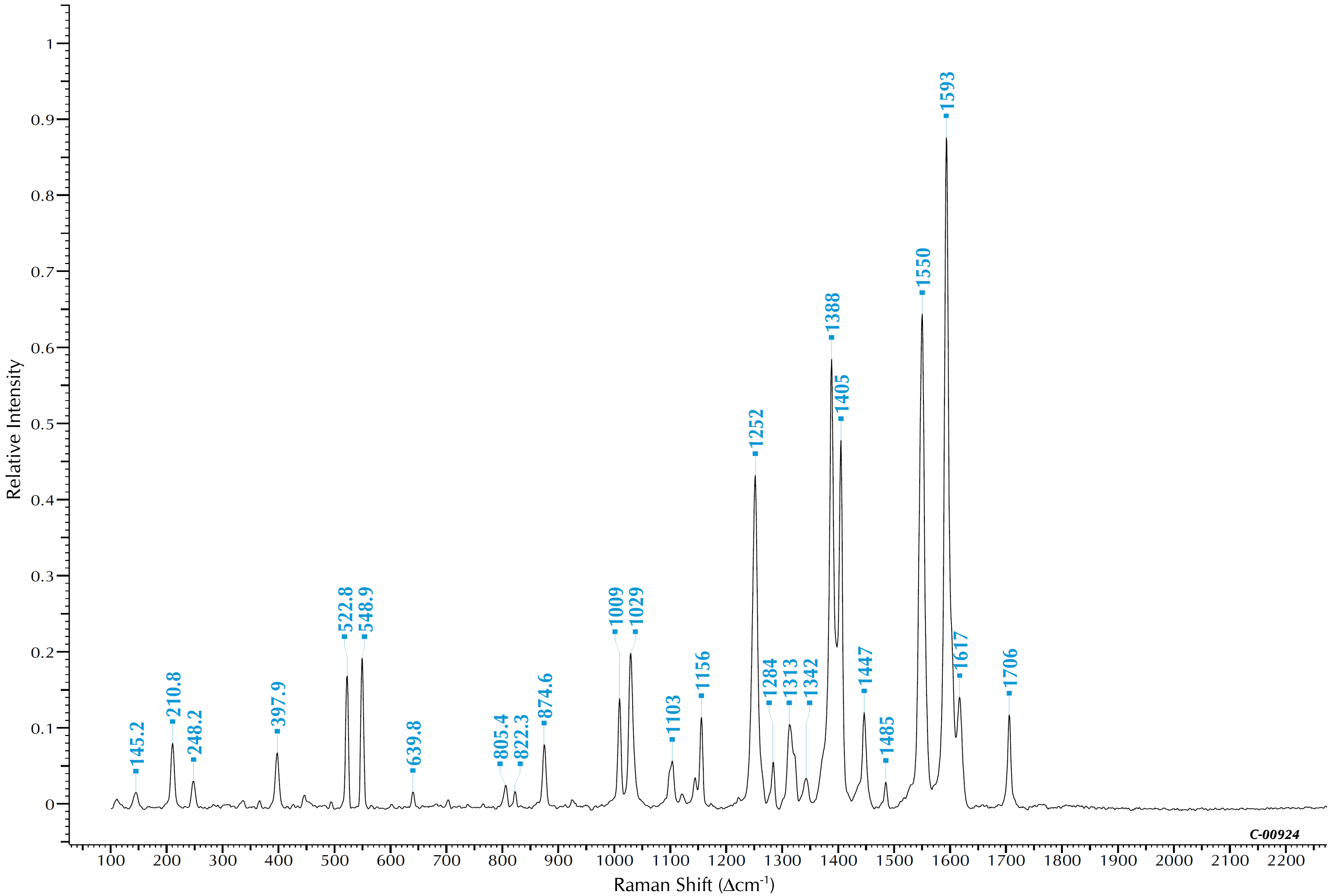
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12367

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Orange 43



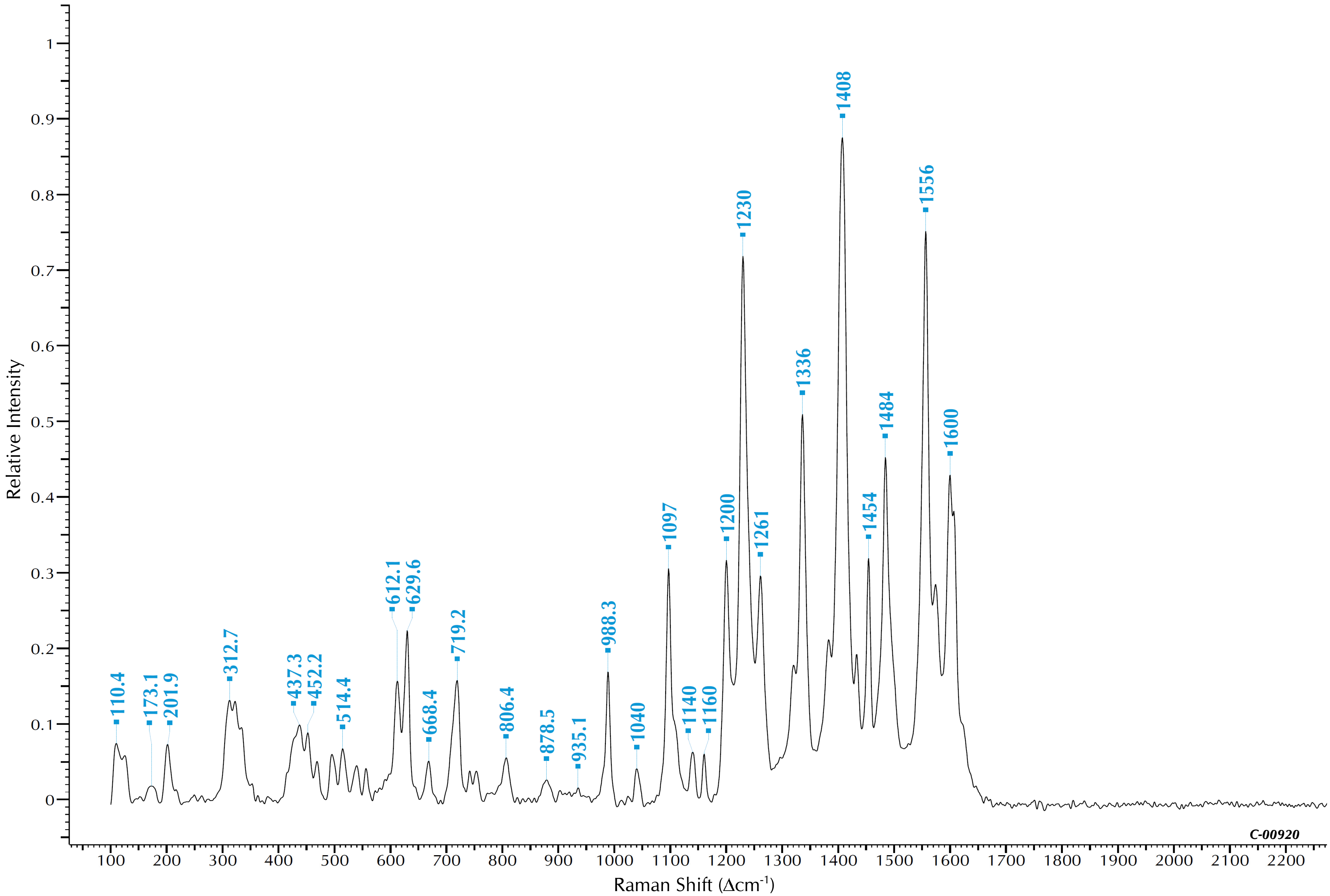
Chemical Category: Organic - Polycyclic - Perinone
Constitution Number: 71105

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Orange 46



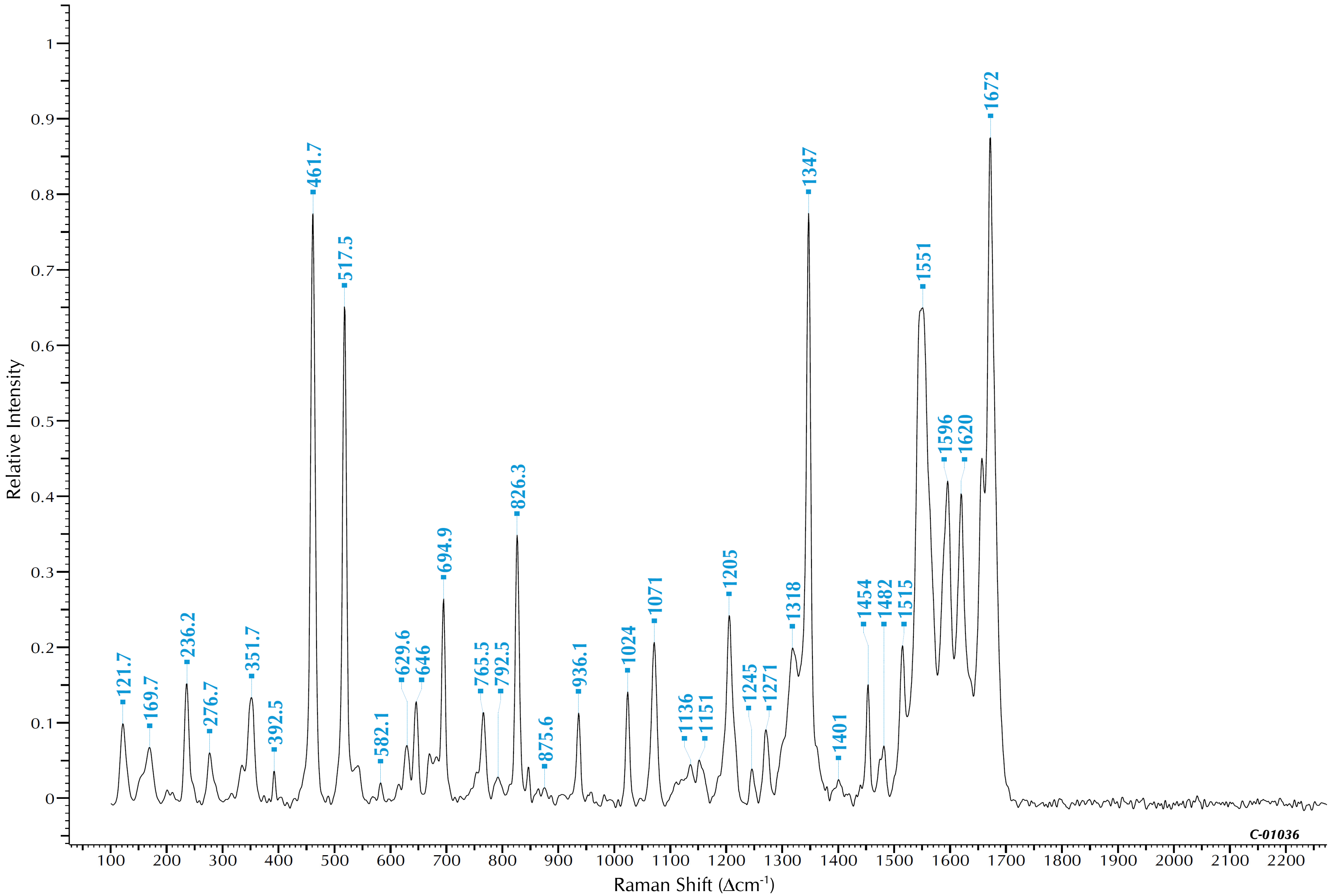
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake
Constitution Number: 15602

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Orange 48



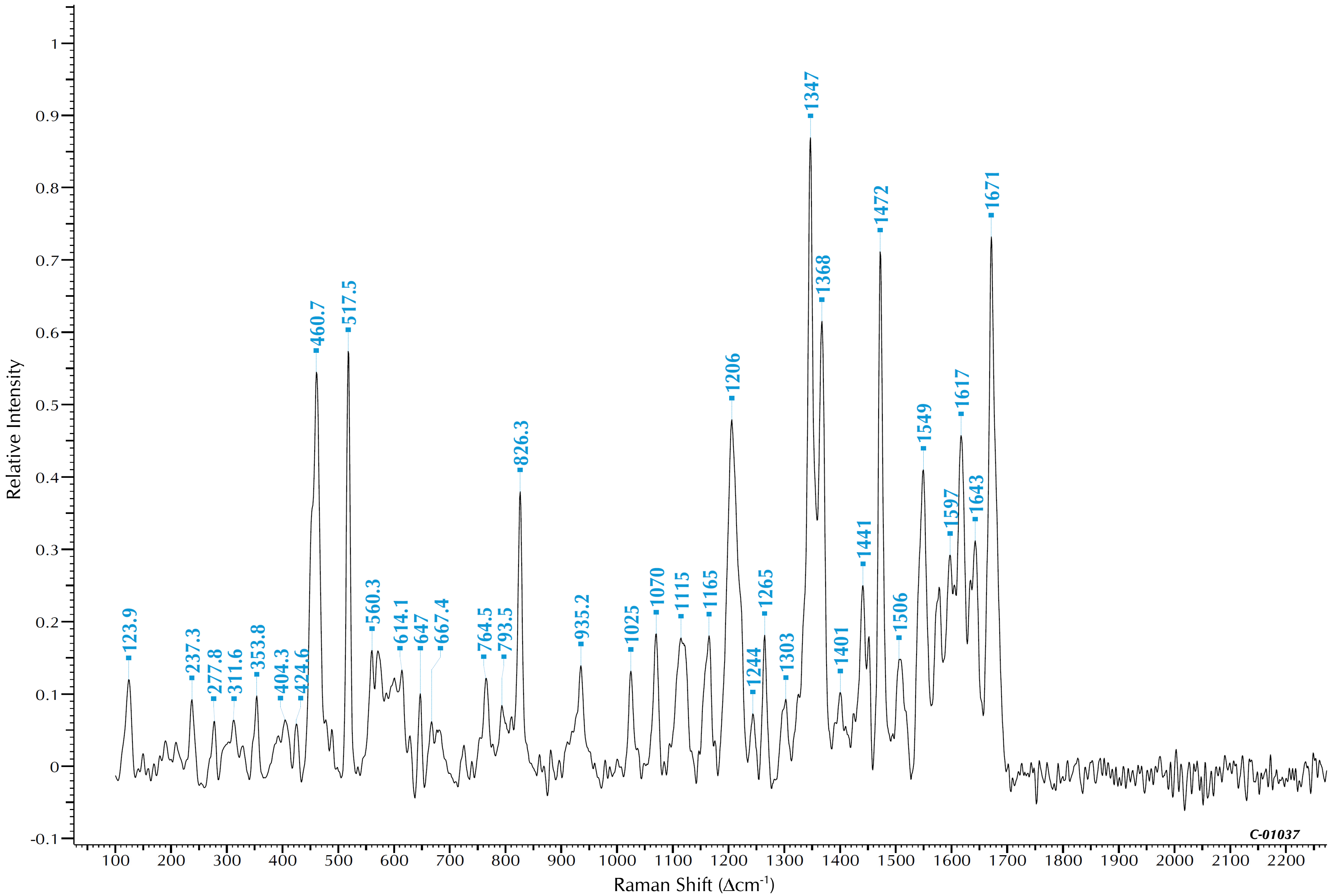
Chemical Category: Organic - Polycyclic - Quinacridone - Quinone
Constitution Number: 73900 73920

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Orange 49



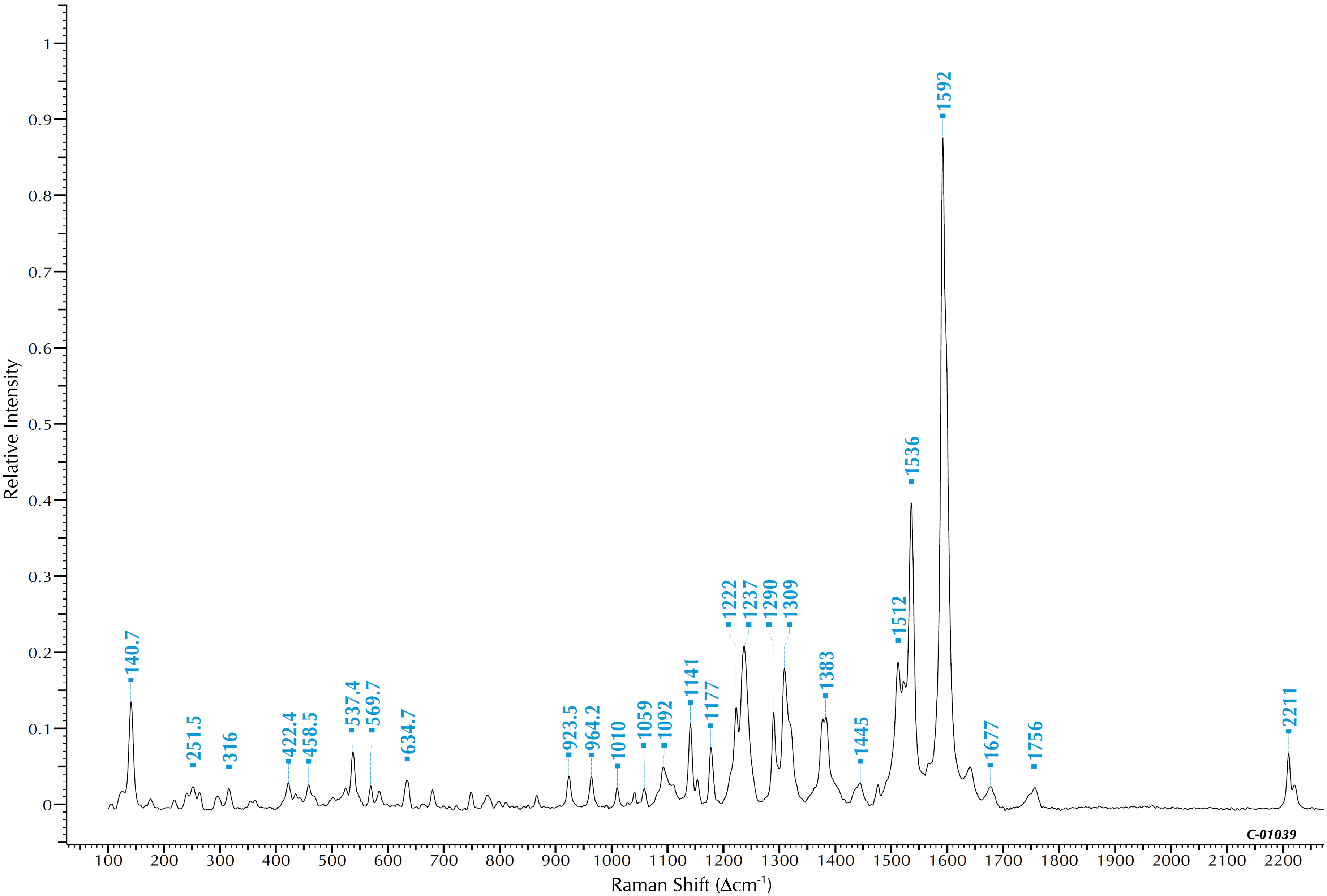
Chemical Category: Organic - Polycyclic - Quinacridone - Quinone
Constitution Number: 73900 73920

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Orange 51



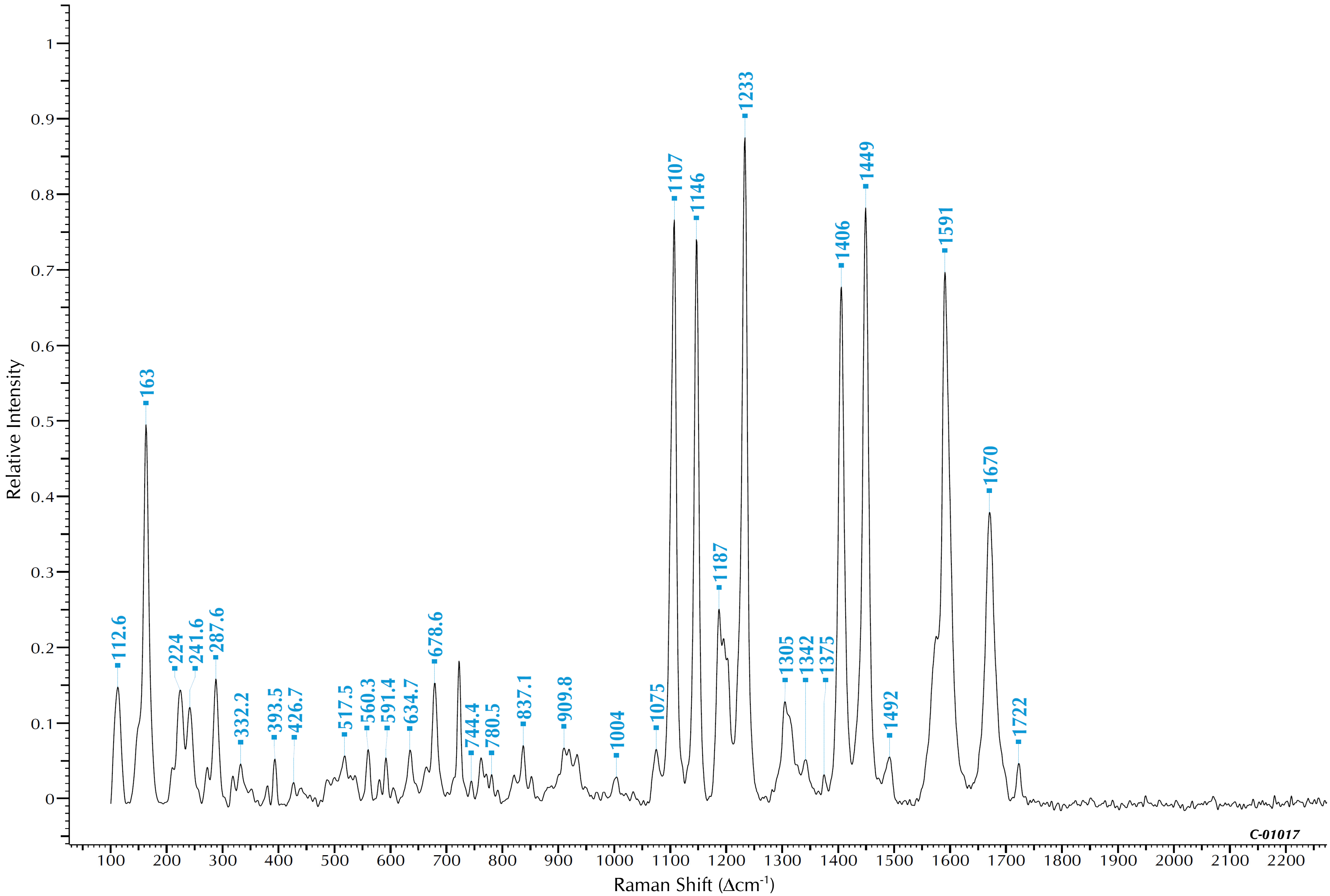
Chemical Category: Organic - Polycyclic - Polycarbocyclic Anthraquinone - Pyranthrone
Constitution Number: Unknown

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Orange 61



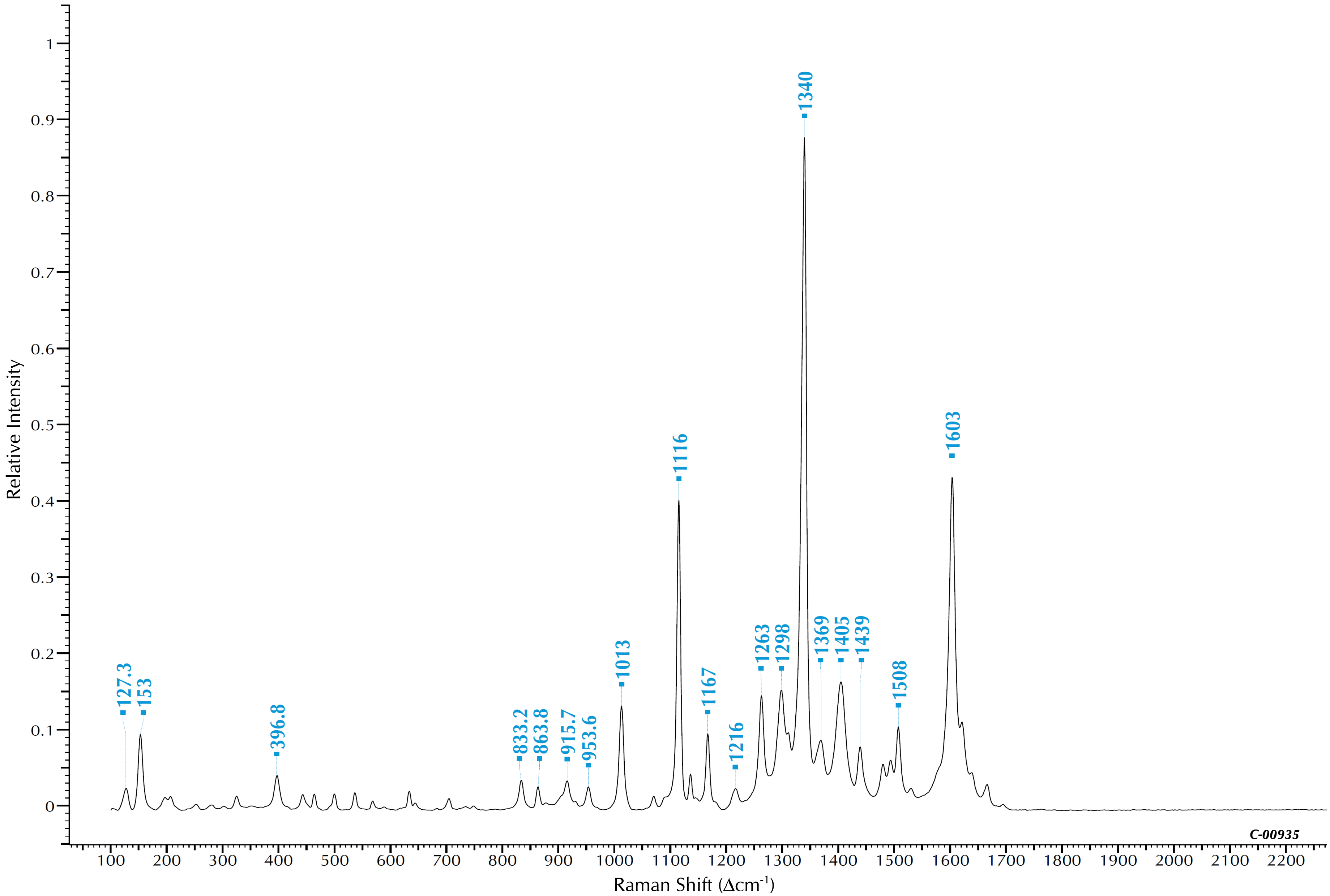
Chemical Category: Organic - Azo - Isoindolinone - Azomethine
Constitution Number: 11265

Bleaching Time (s): 60
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 62



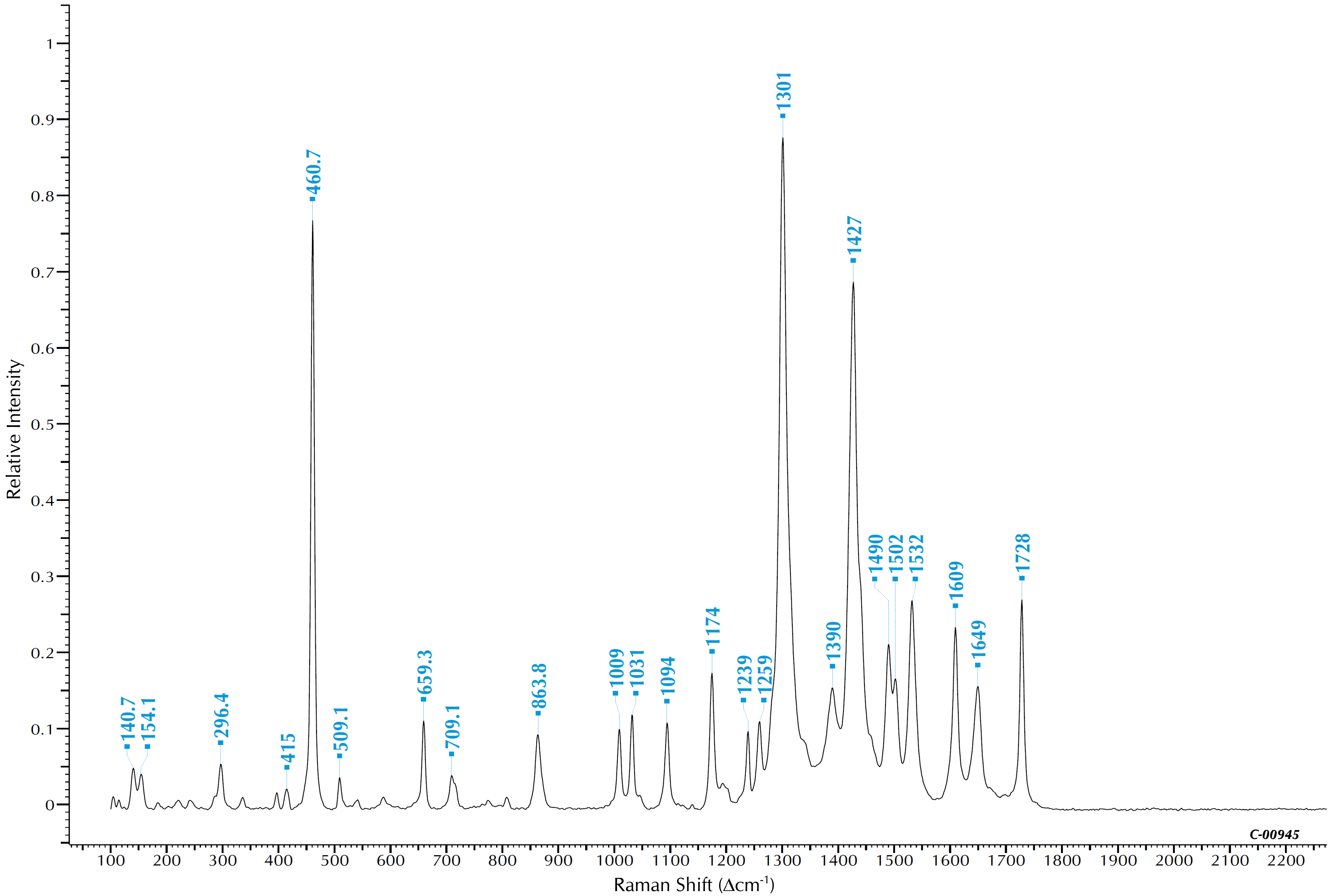
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 11775

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 64



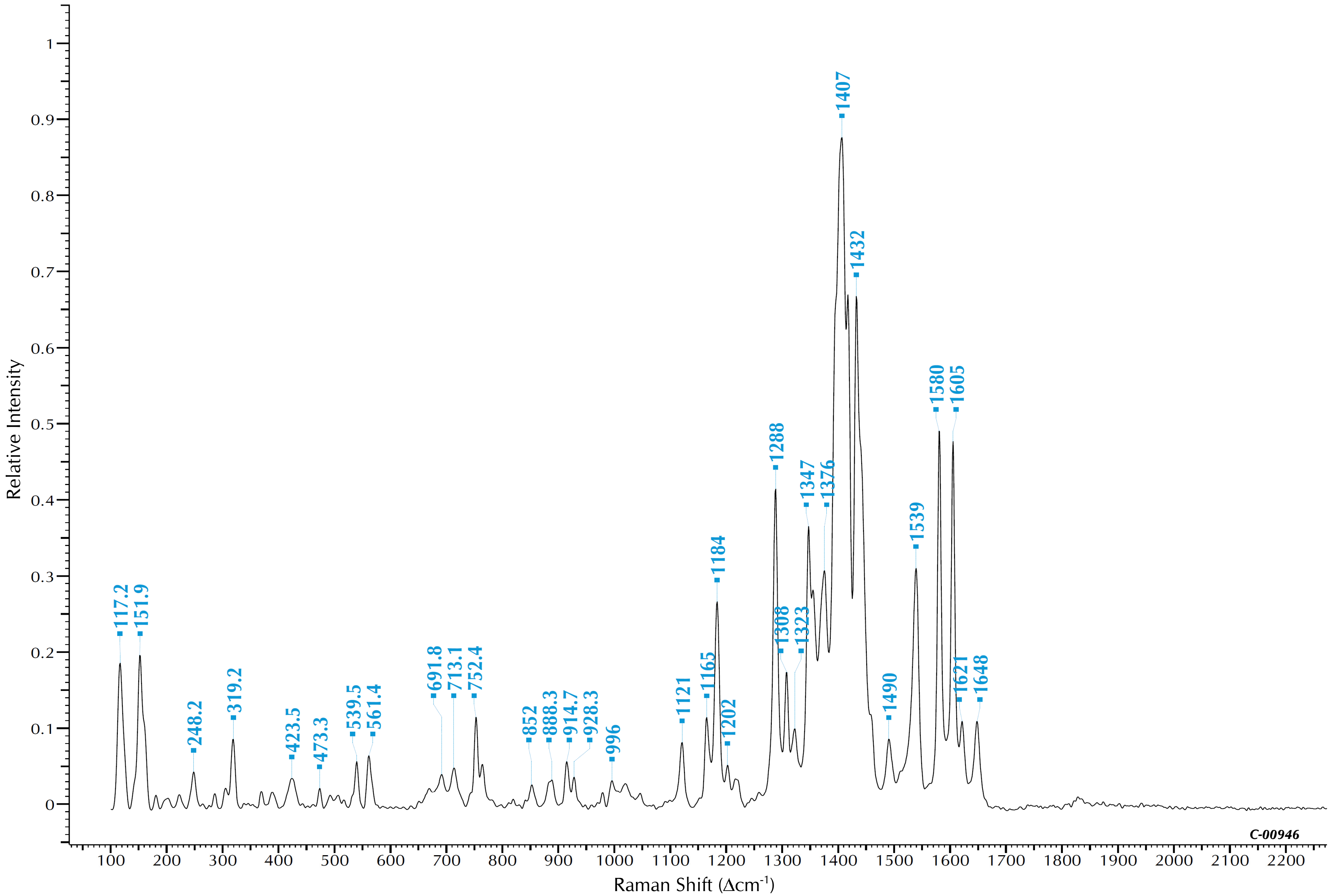
Chemical Category: Organic - Other - Azoheterocyclus
Constitution Number: 12760

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 68



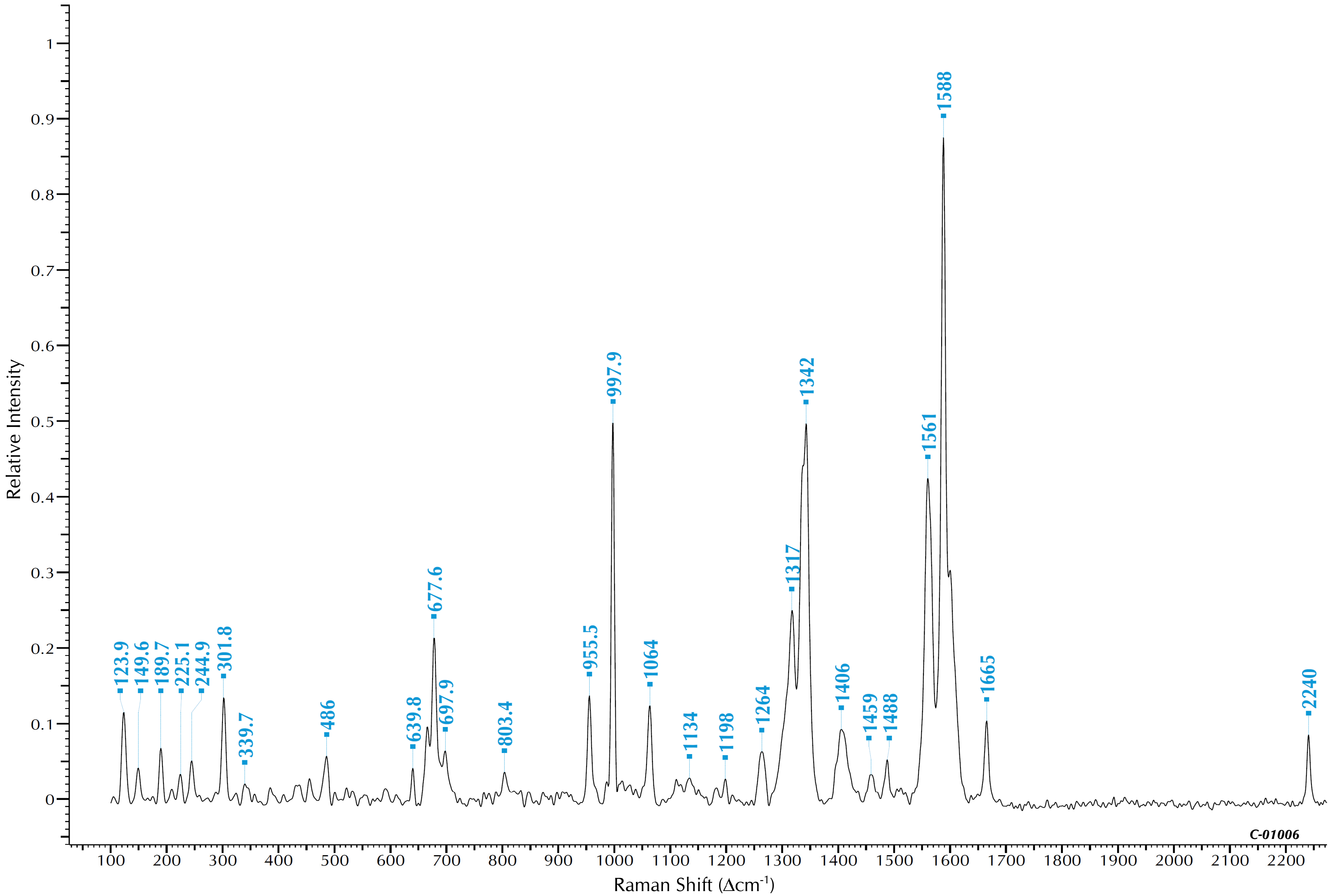
Chemical Category: Organic - Azo - Metal Complex - Azomethine
Constitution Number: 486150

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 71



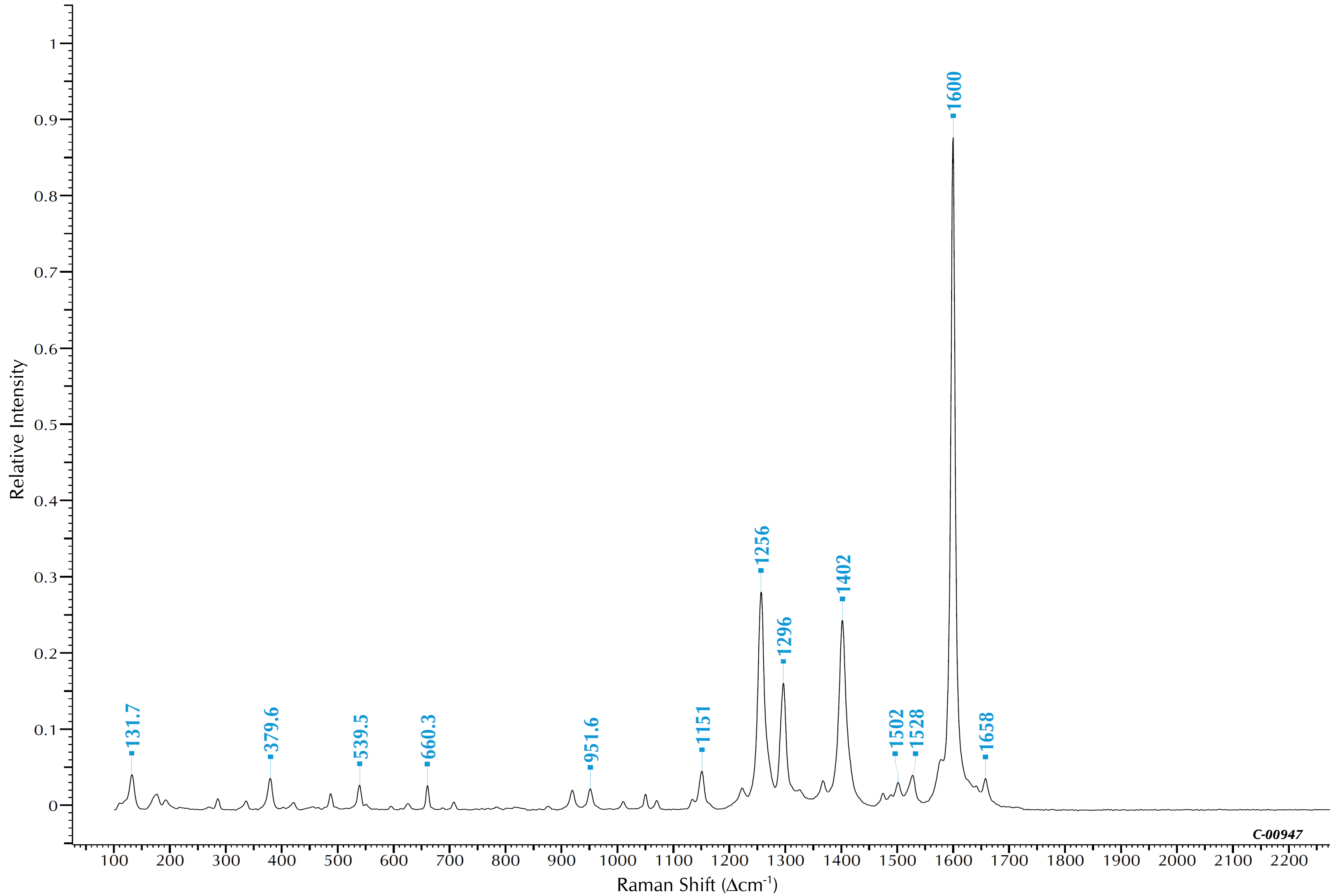
Chemical Category: Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)
Constitution Number: 561200

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 72



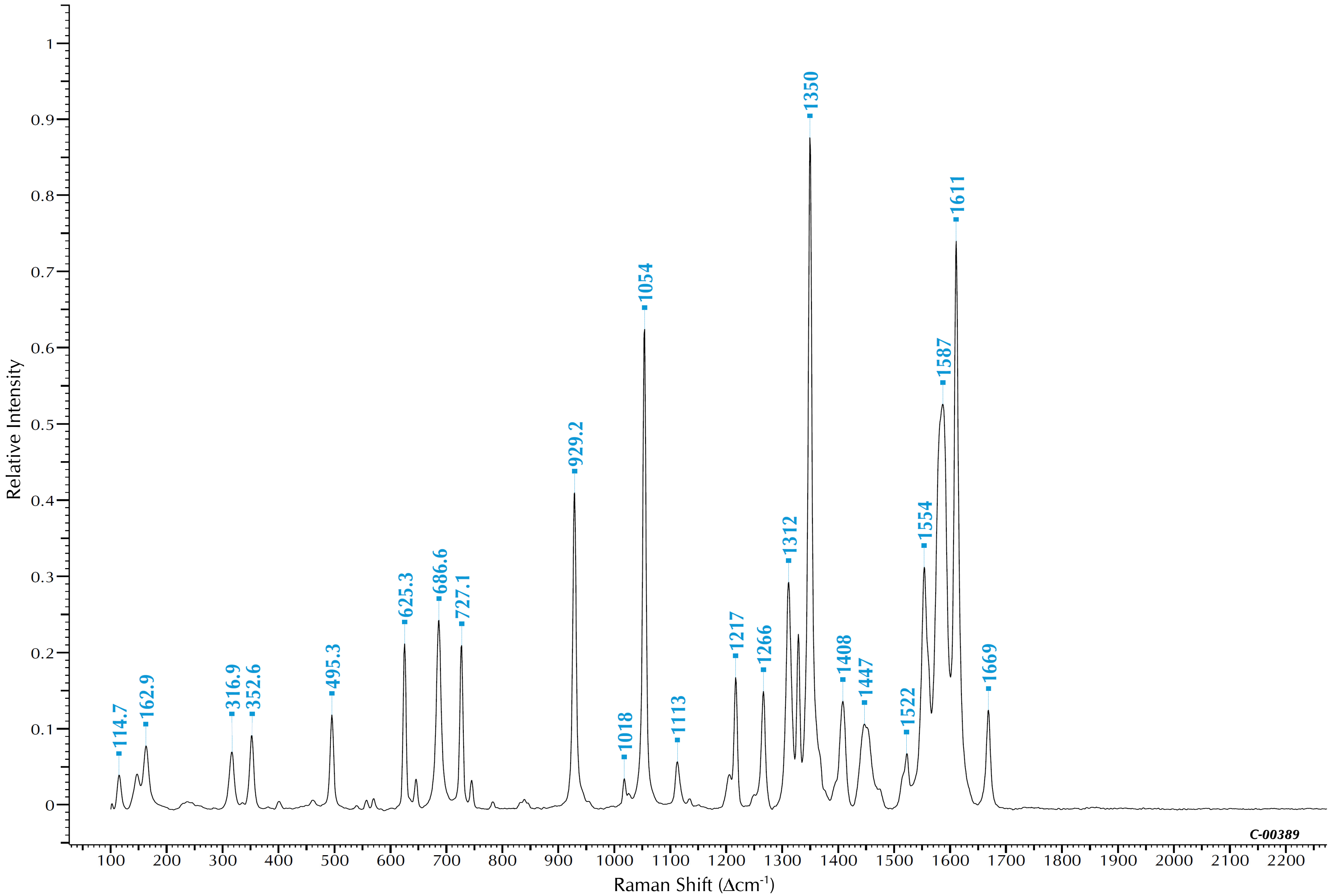
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 211095

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 73



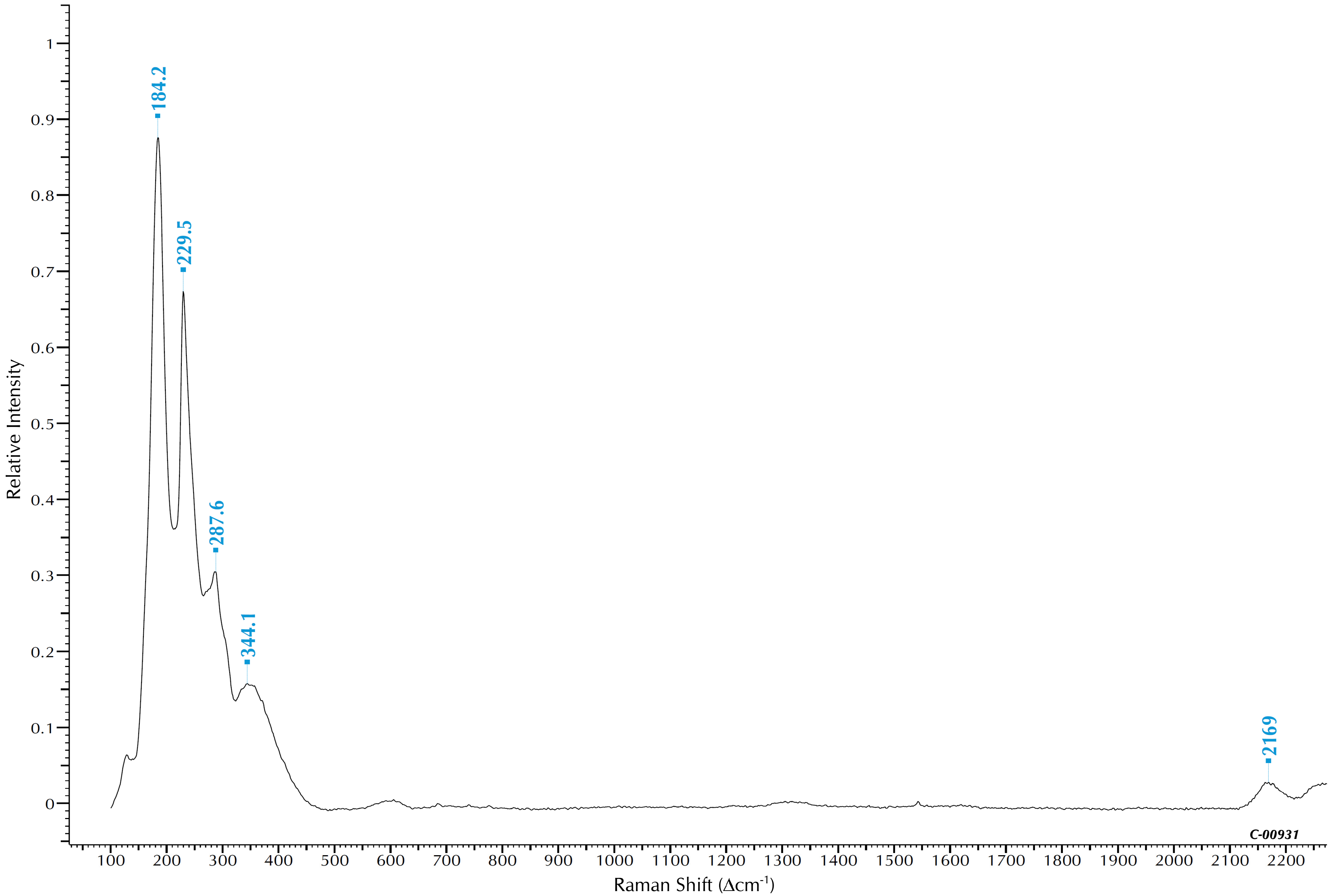
Chemical Category: Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)
Constitution Number: 561170

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Orange 75

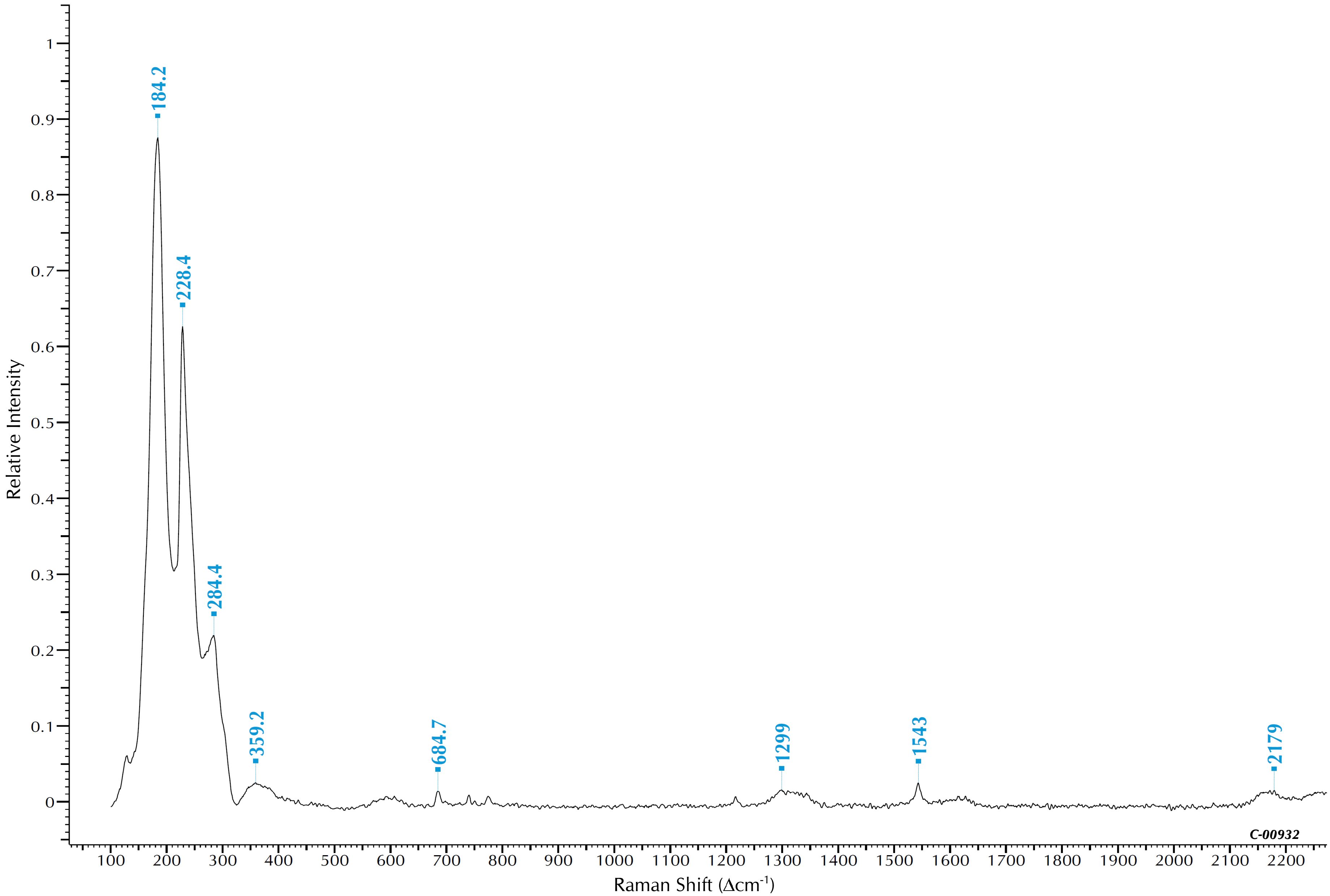


Chemical Category: Inorganic - Sulfide
Constitution Number: 77283:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

C.I. Pigment Orange 78



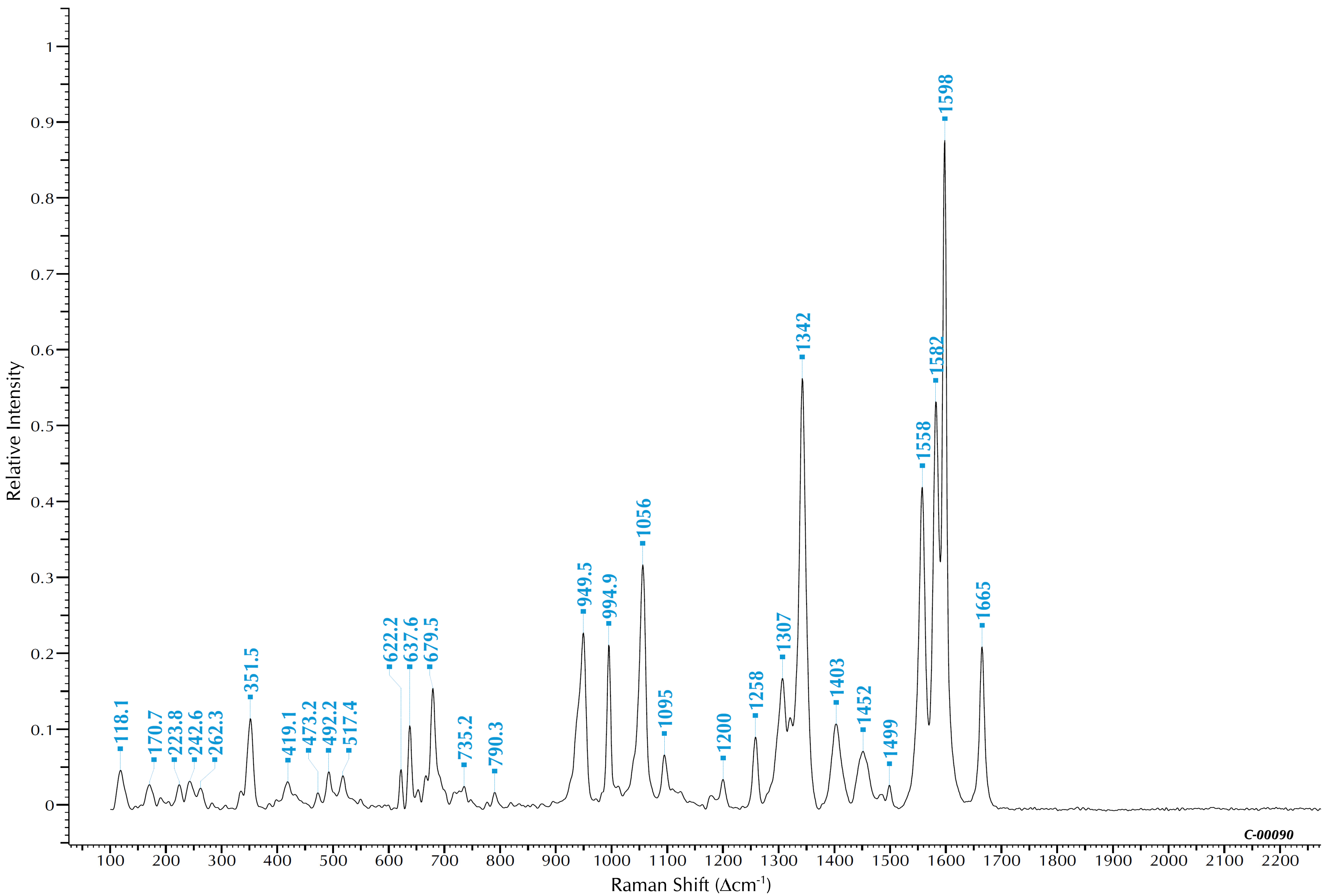
Chemical Category: Inorganic - Sulfide
Constitution Number: 77285:0

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Orange 107



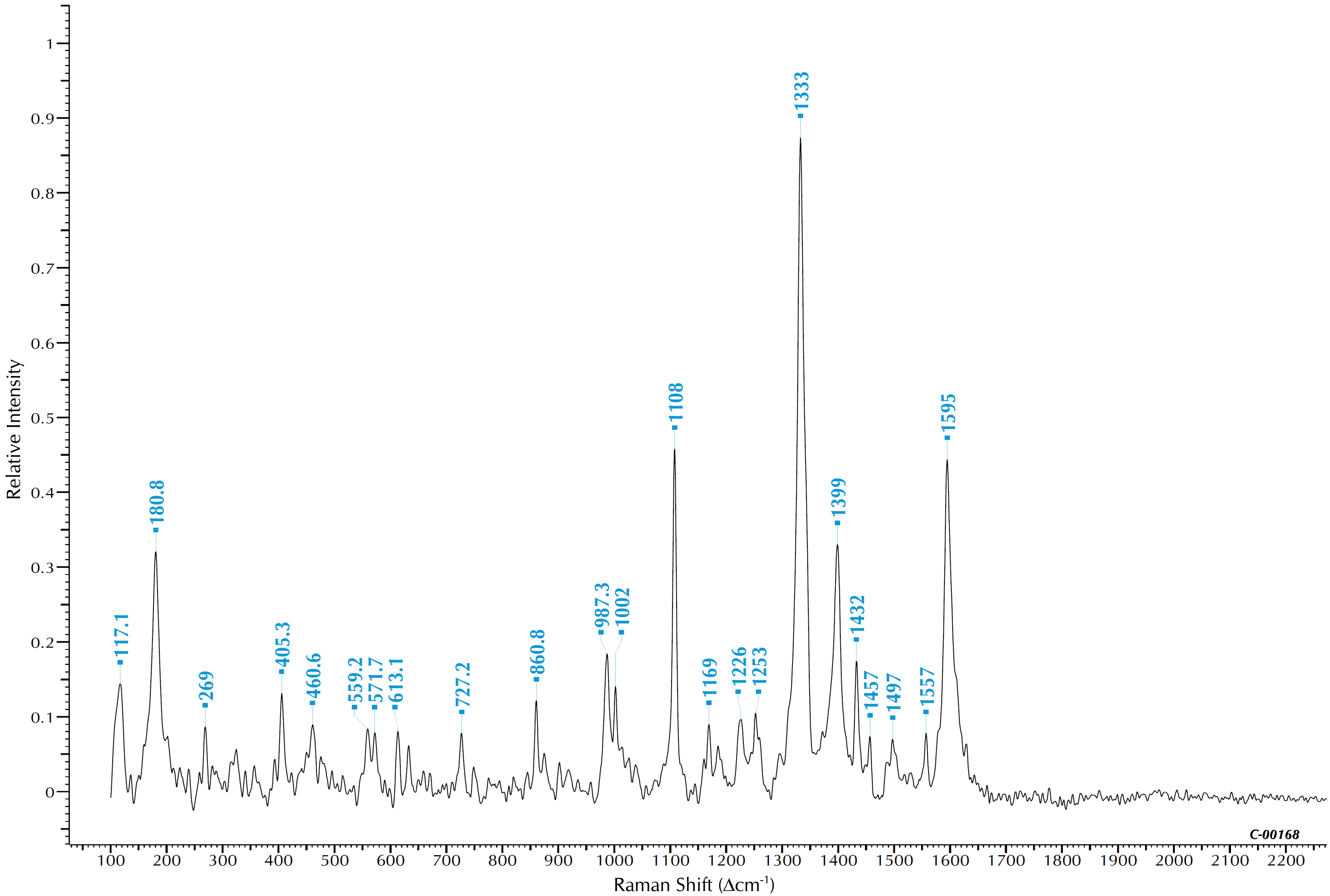
Chemical Category: Organic - Other
Constitution Number: Unknown

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 1



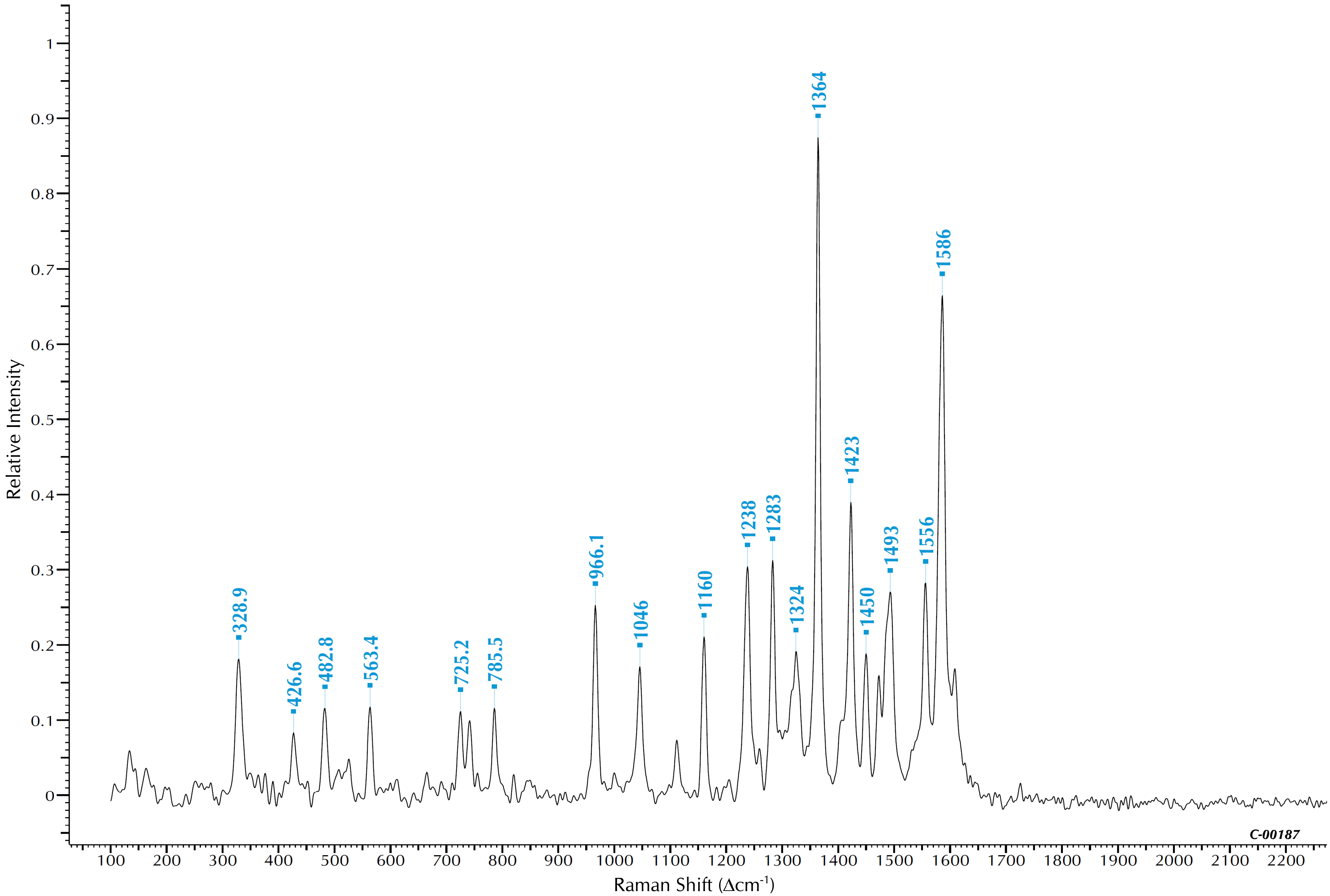
Chemical Category: Organic - Azo - Beta-Napthol
Constitution Number: 12070

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 2



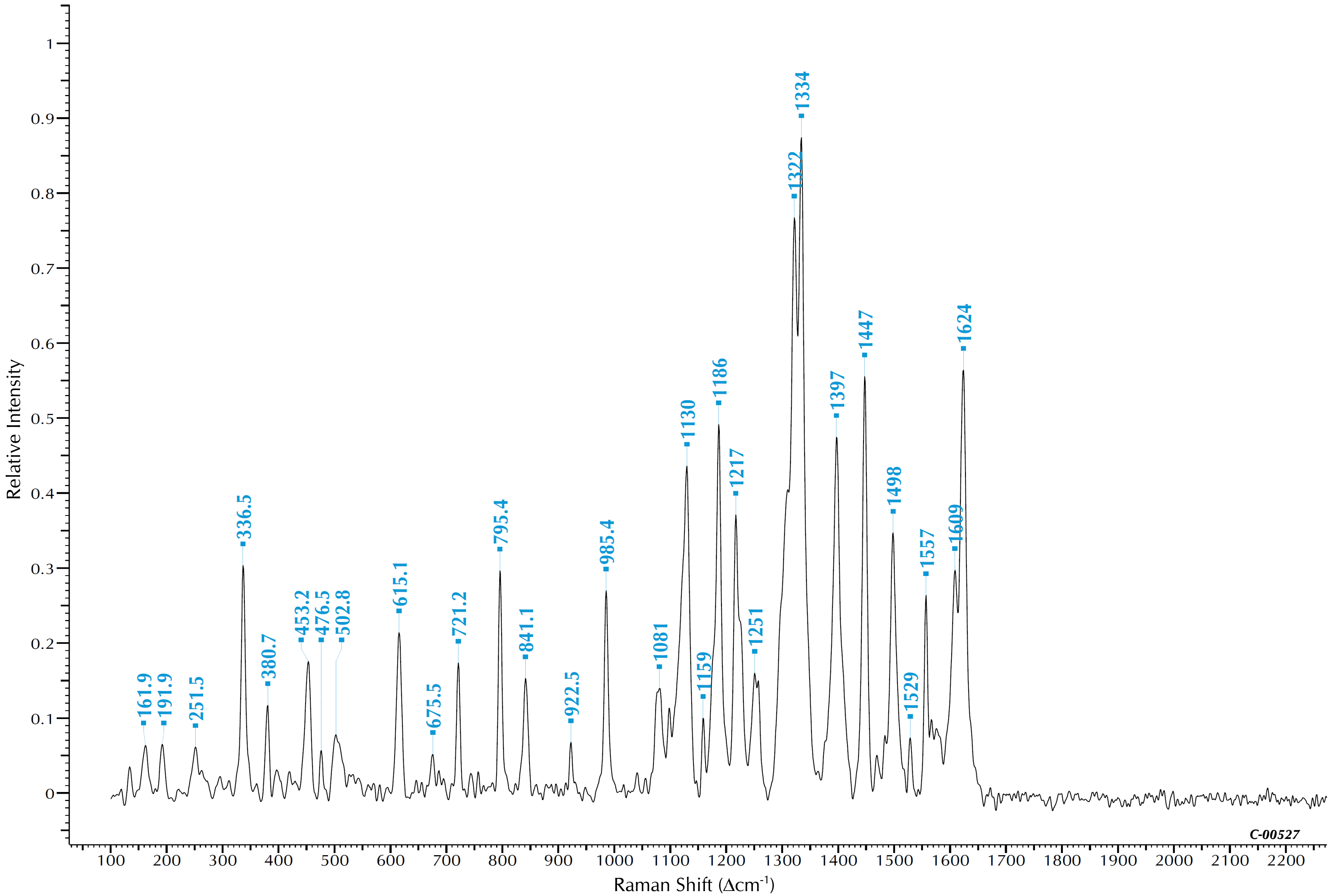
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12310

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 3



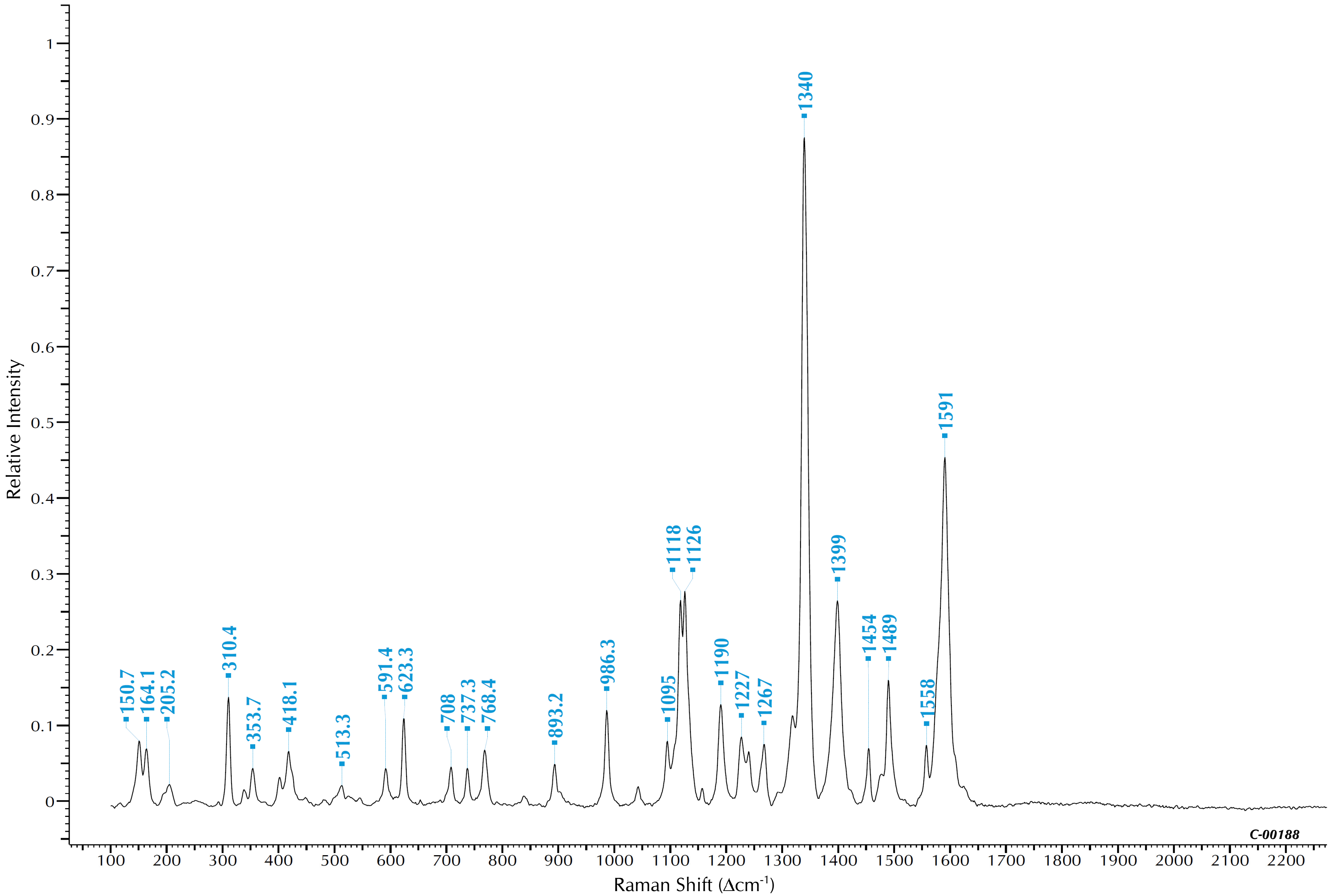
Chemical Category: Organic - Azo - Beta-Napthol
Constitution Number: 12120

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Red 4



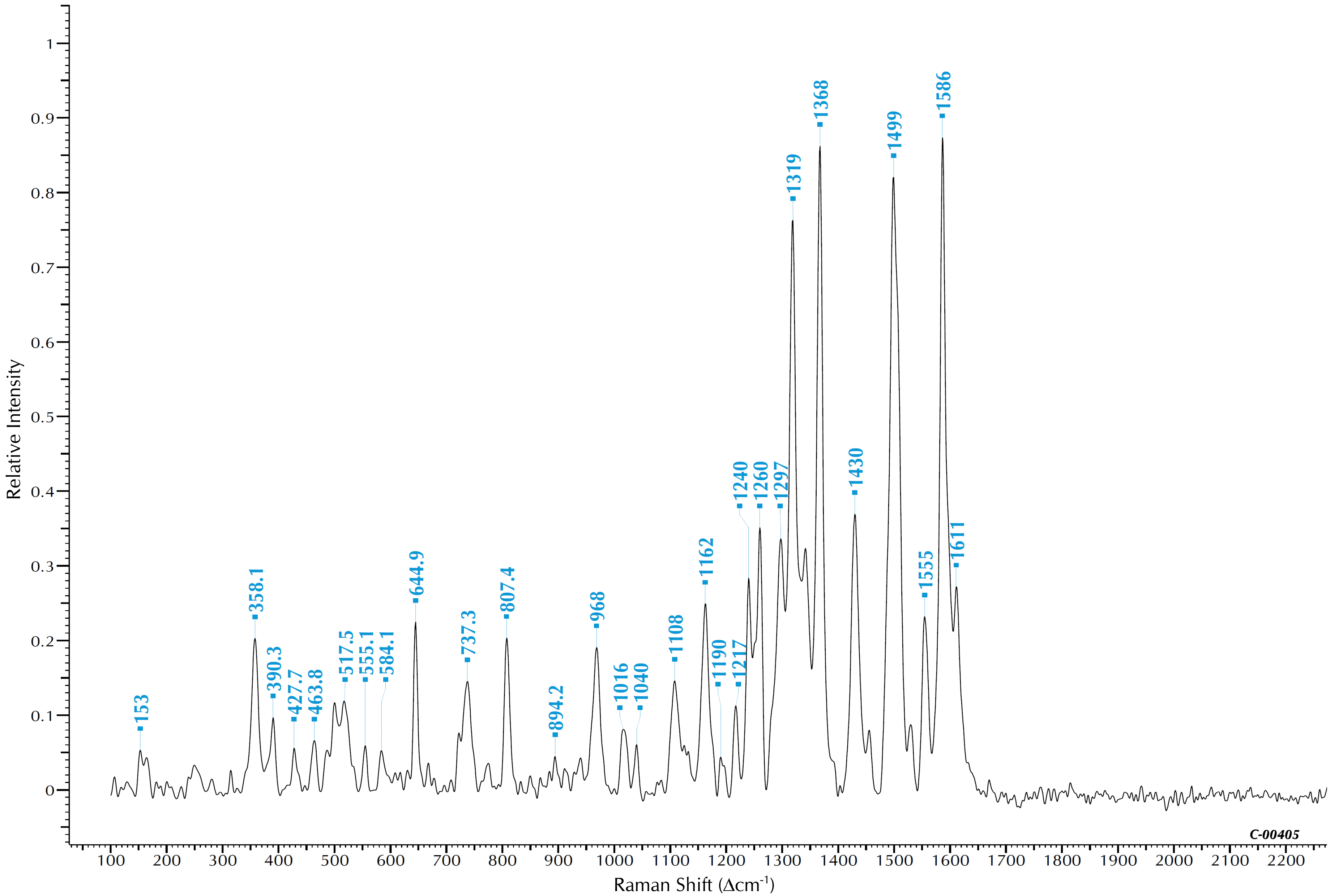
Chemical Category: Organic - Azo - Beta-Napthol
Constitution Number: 12085

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 5



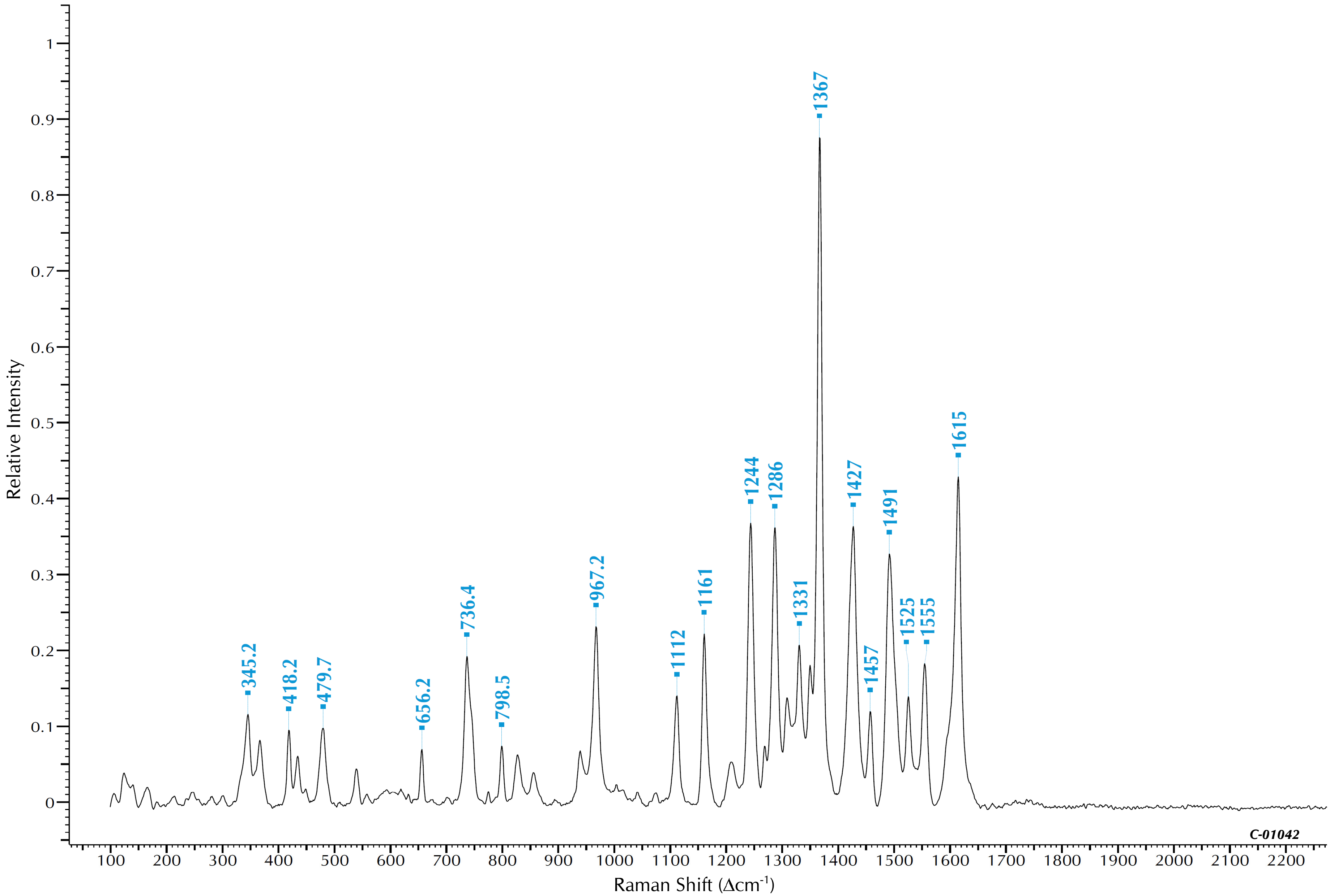
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12490

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 8



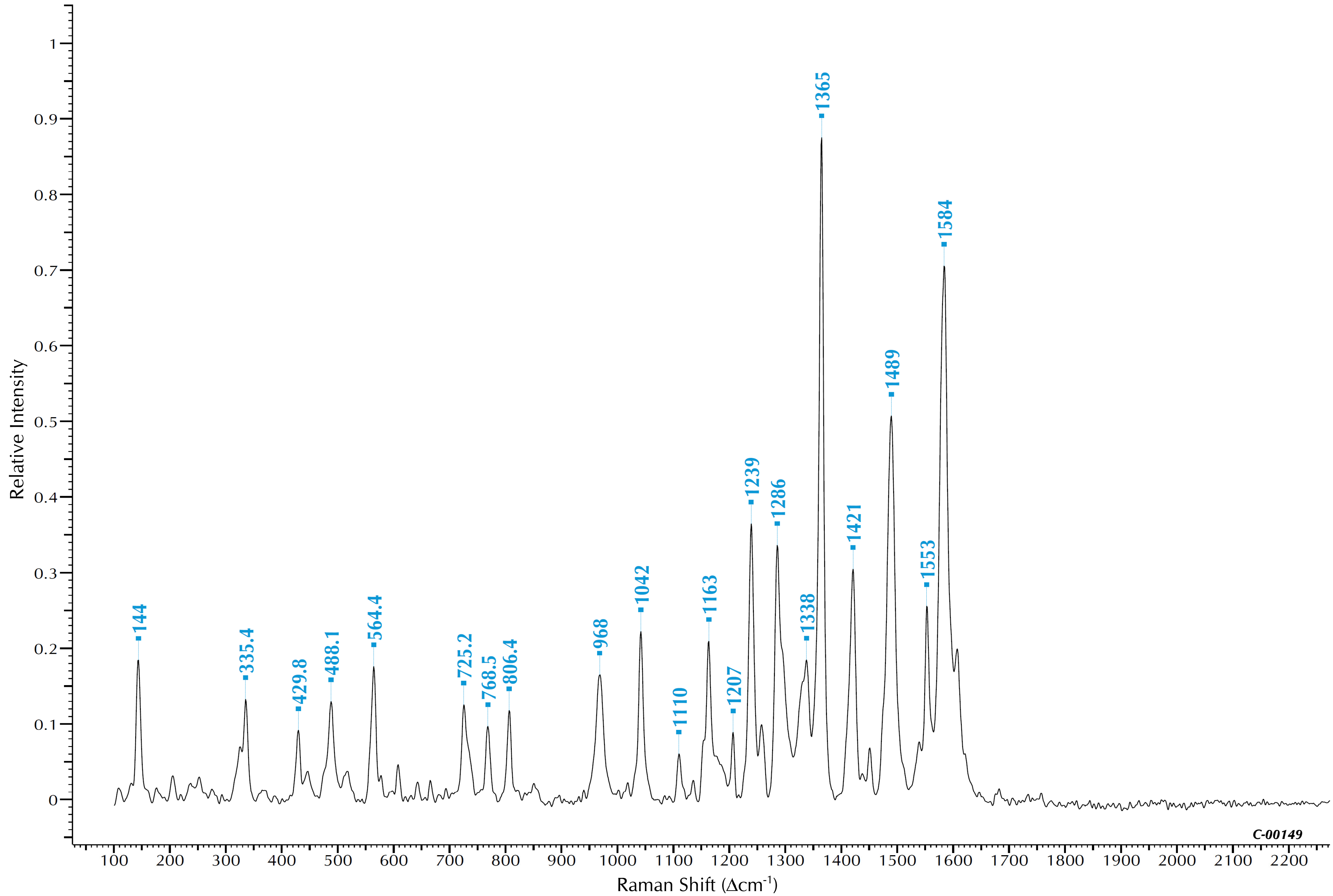
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12335

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 9



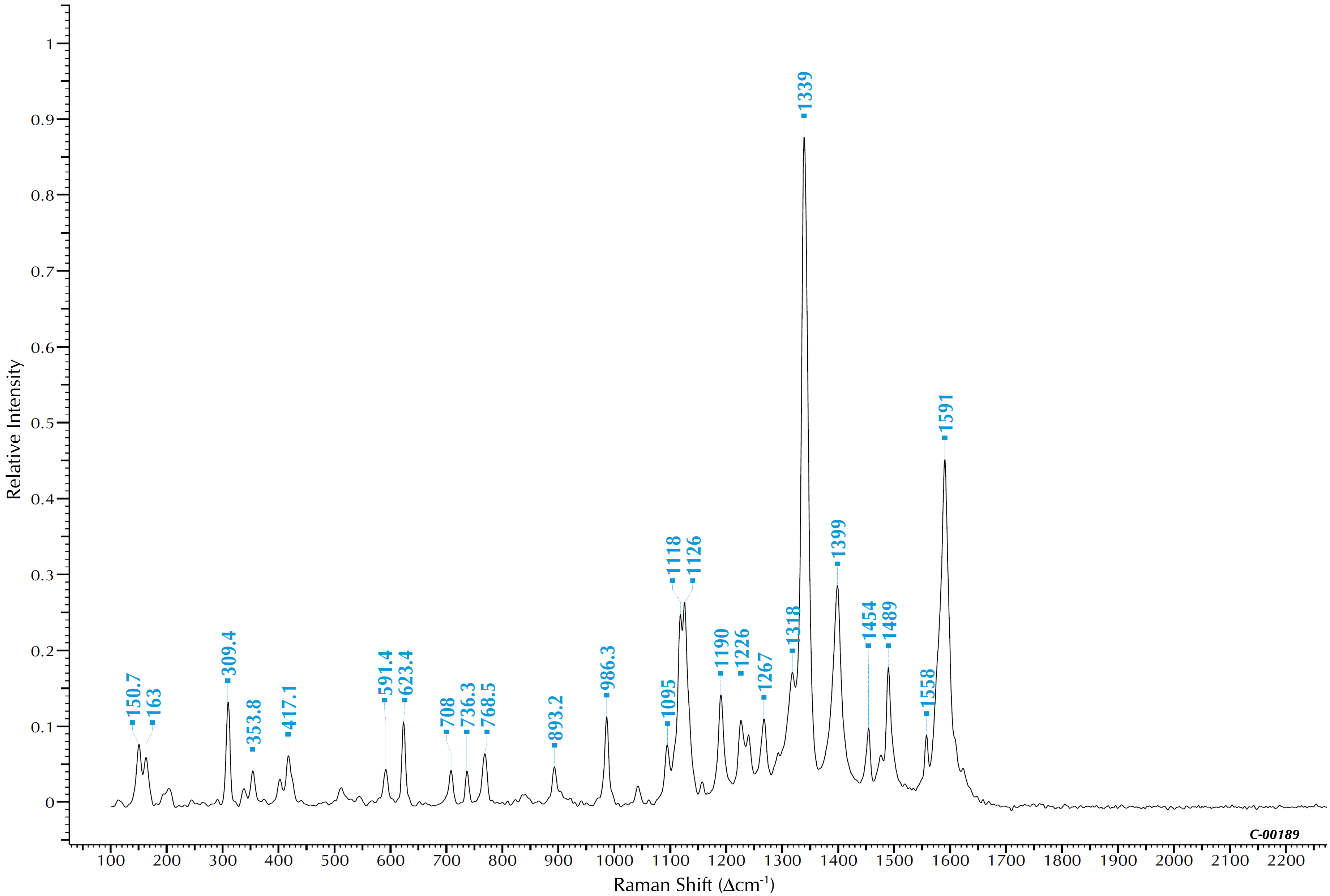
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12460

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 12



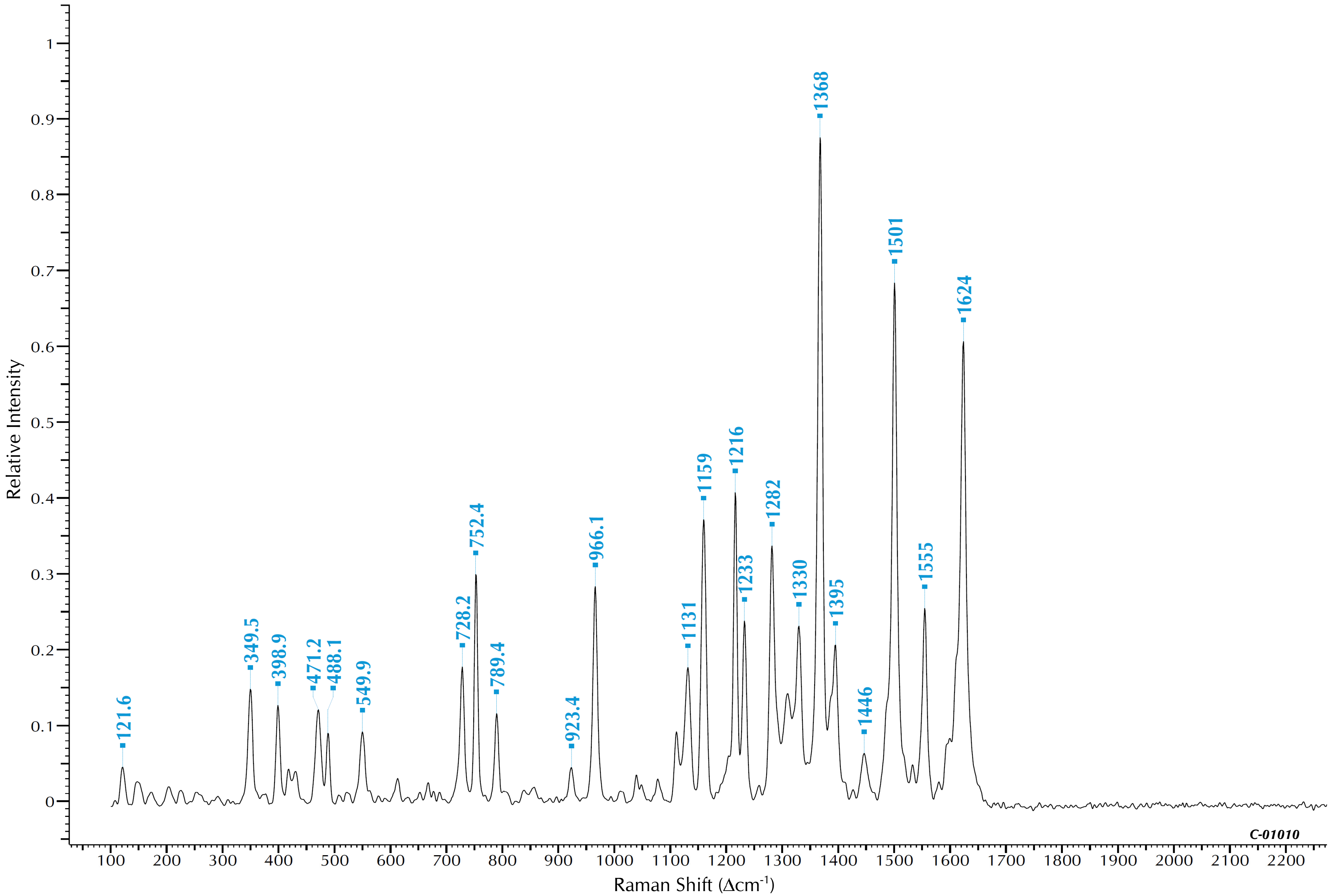
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12385

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 13



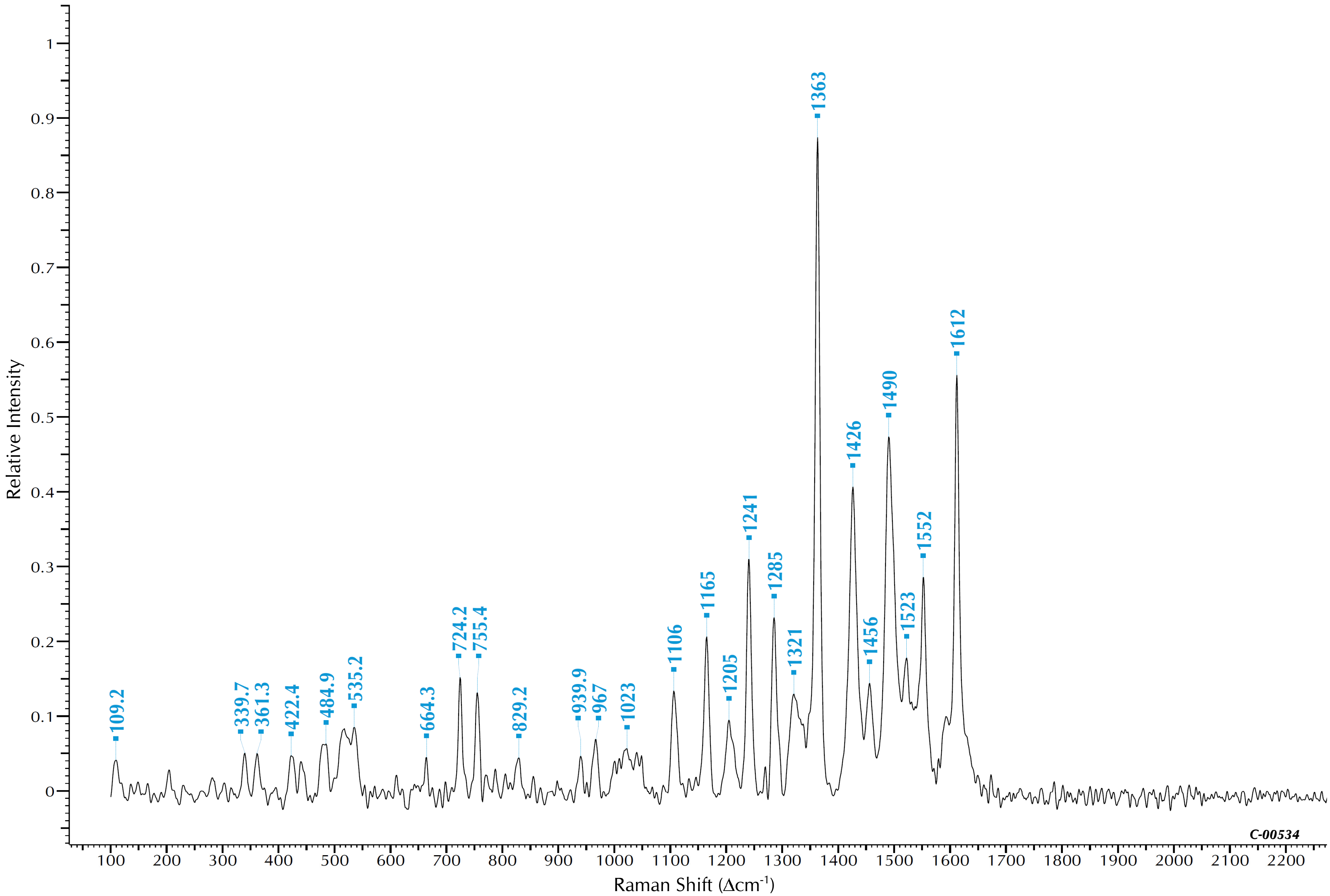
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12395

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 5

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 17



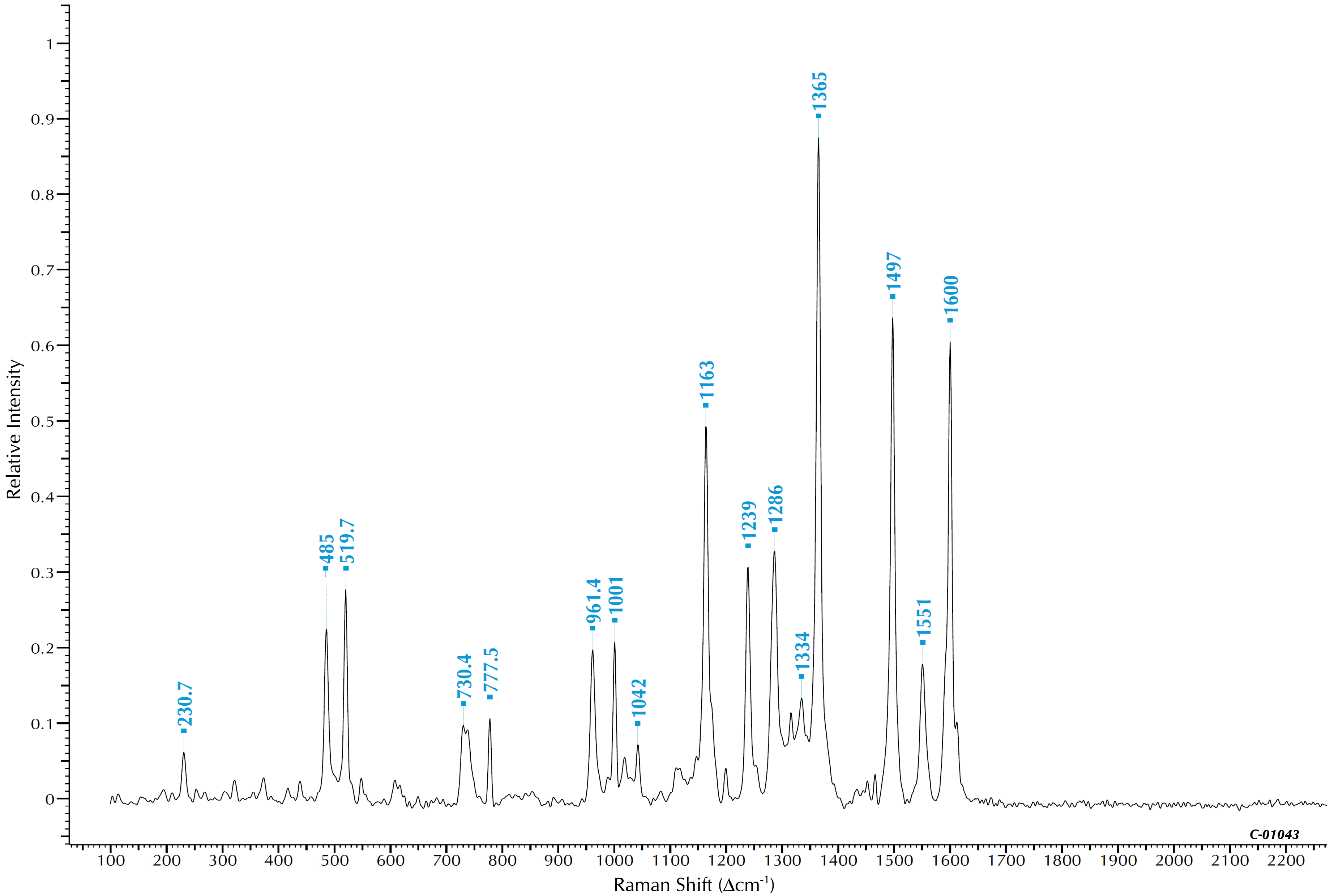
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12390

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Red 21



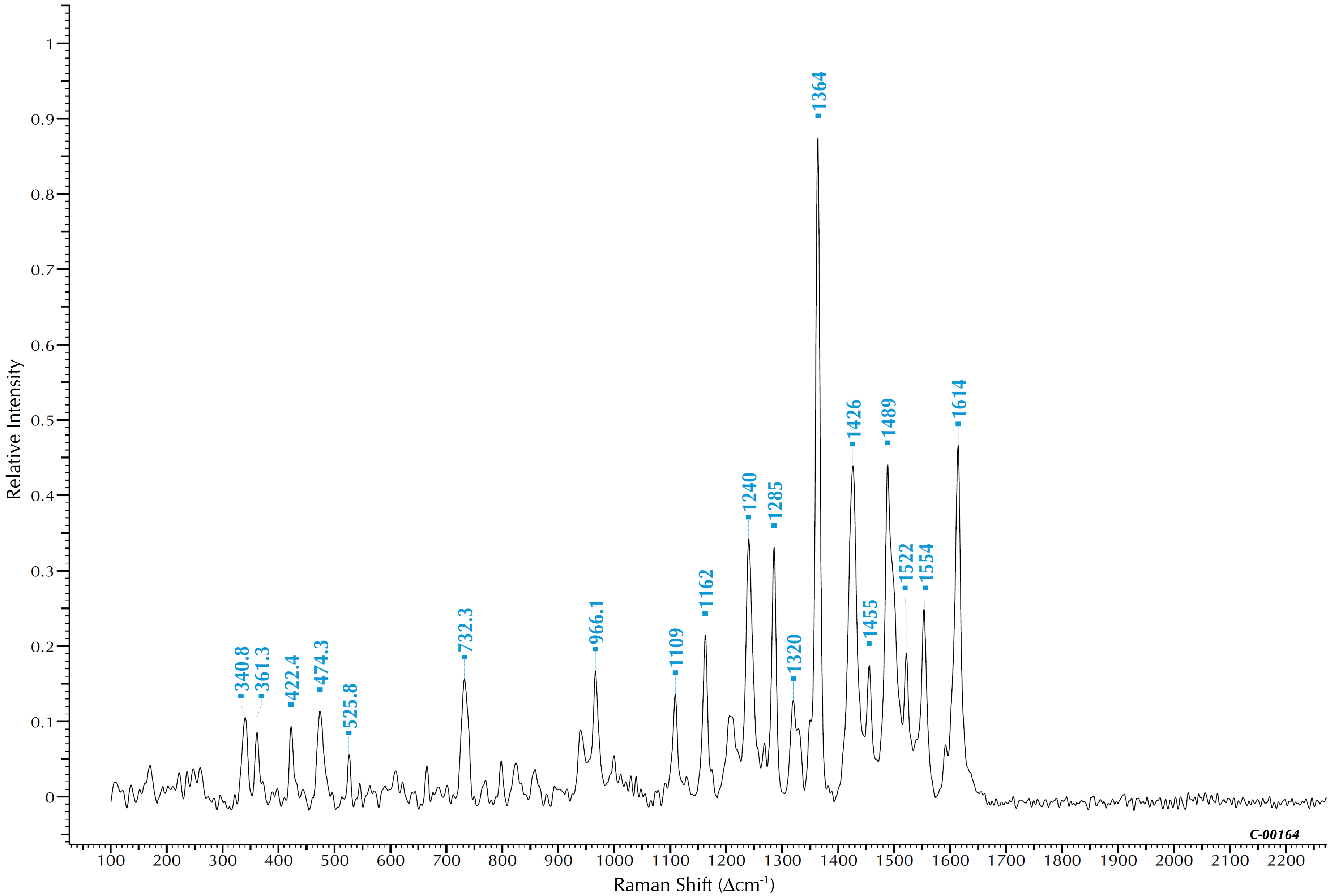
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12300

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 22



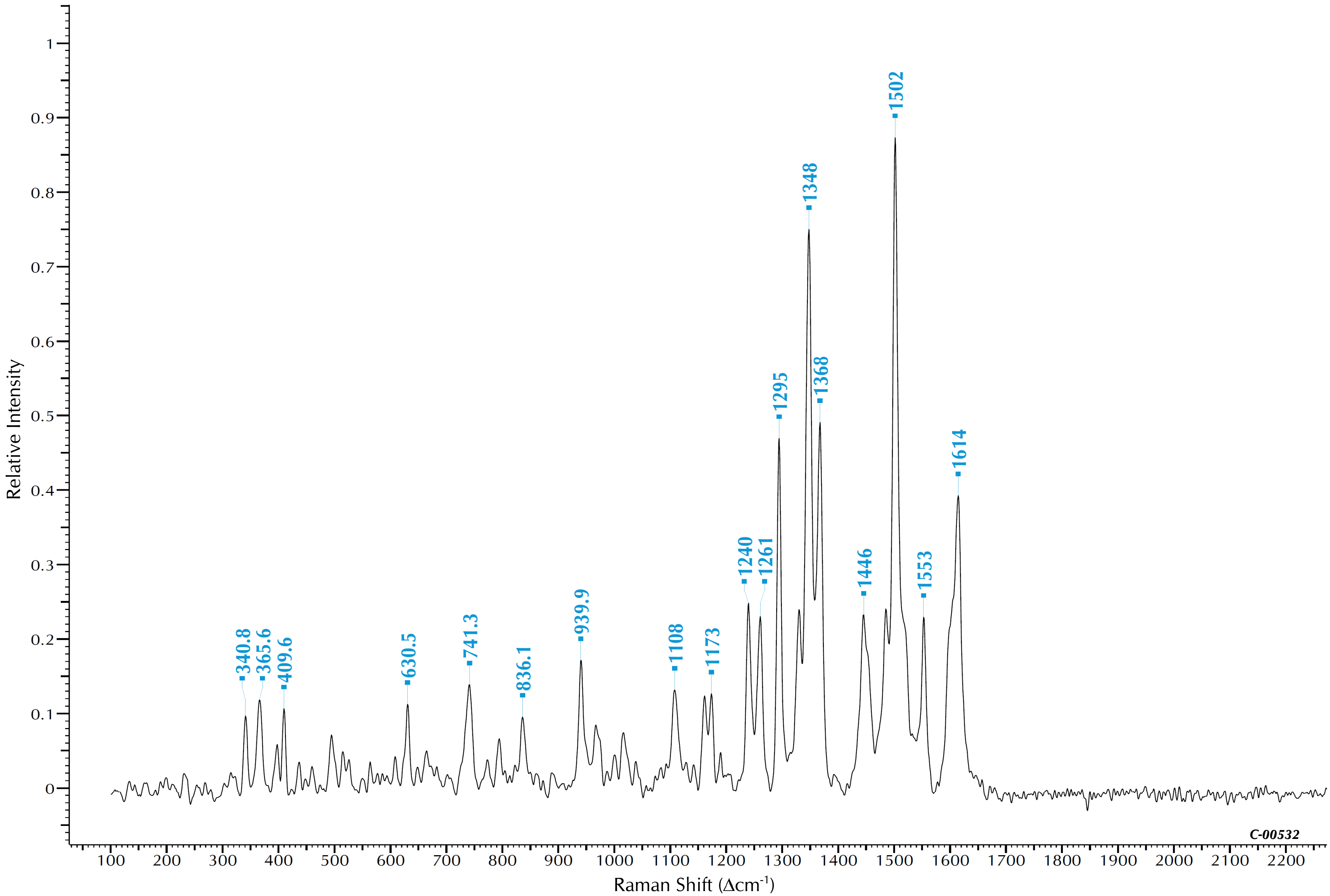
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12315

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 23



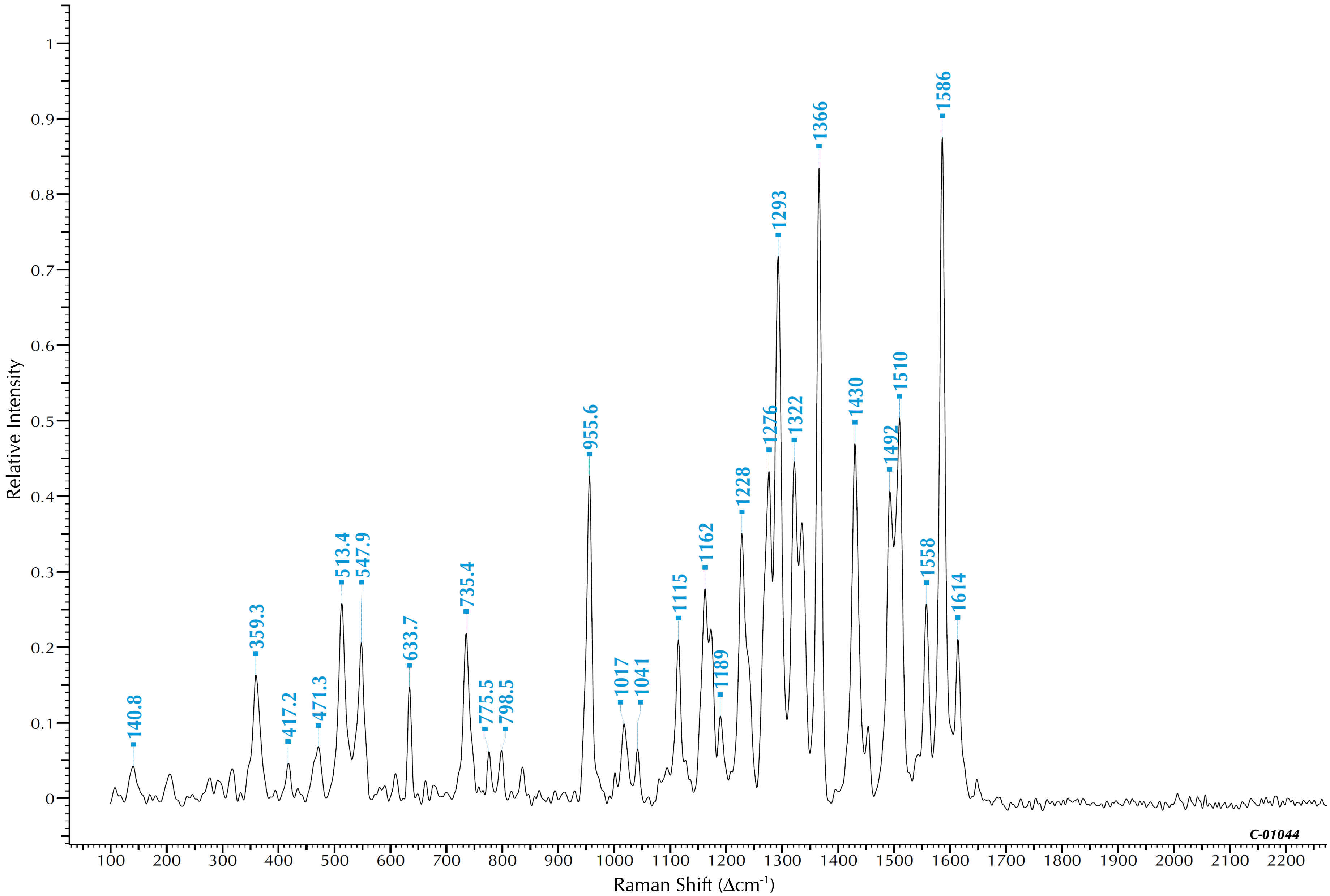
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12355

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Red 31



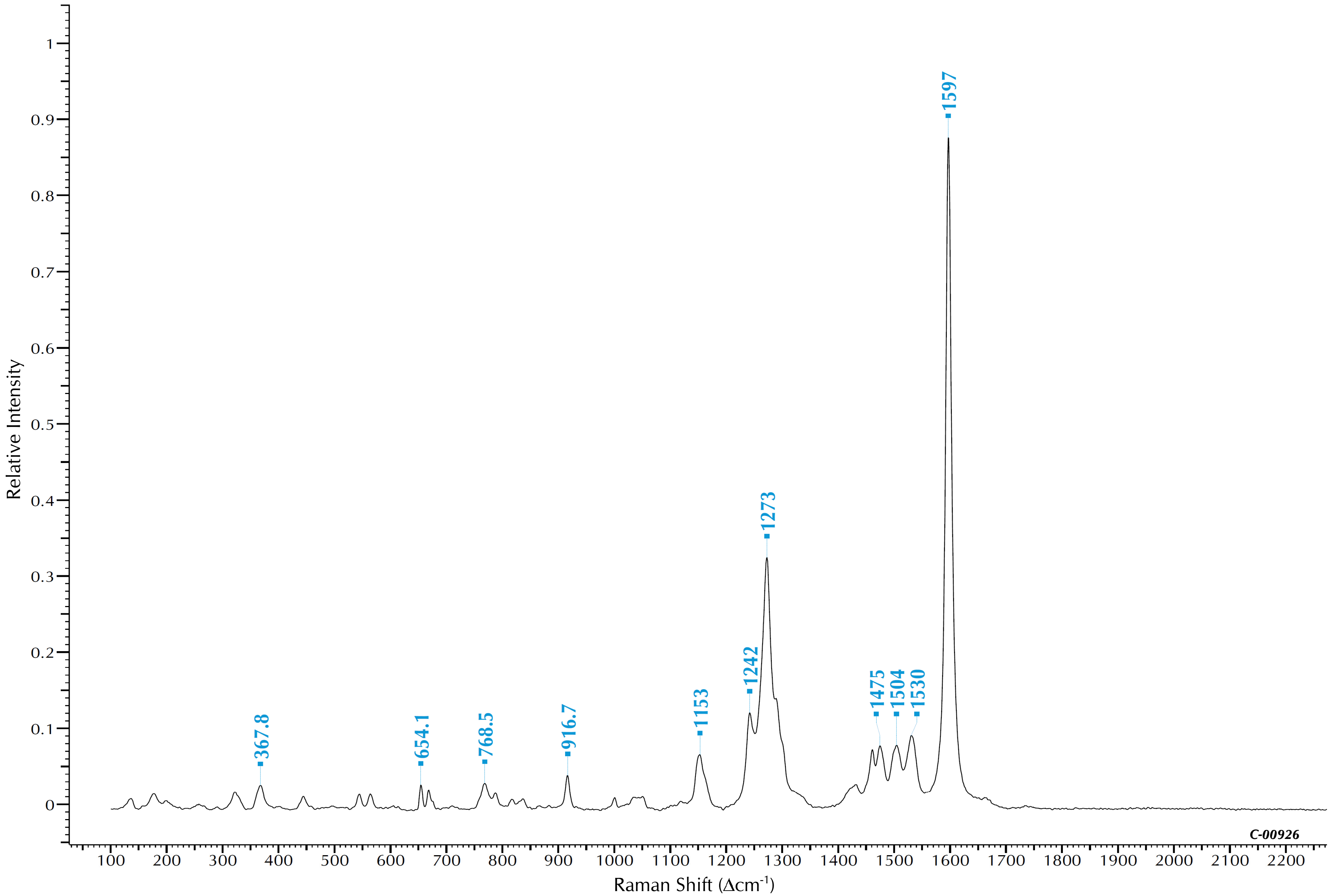
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12360

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 38



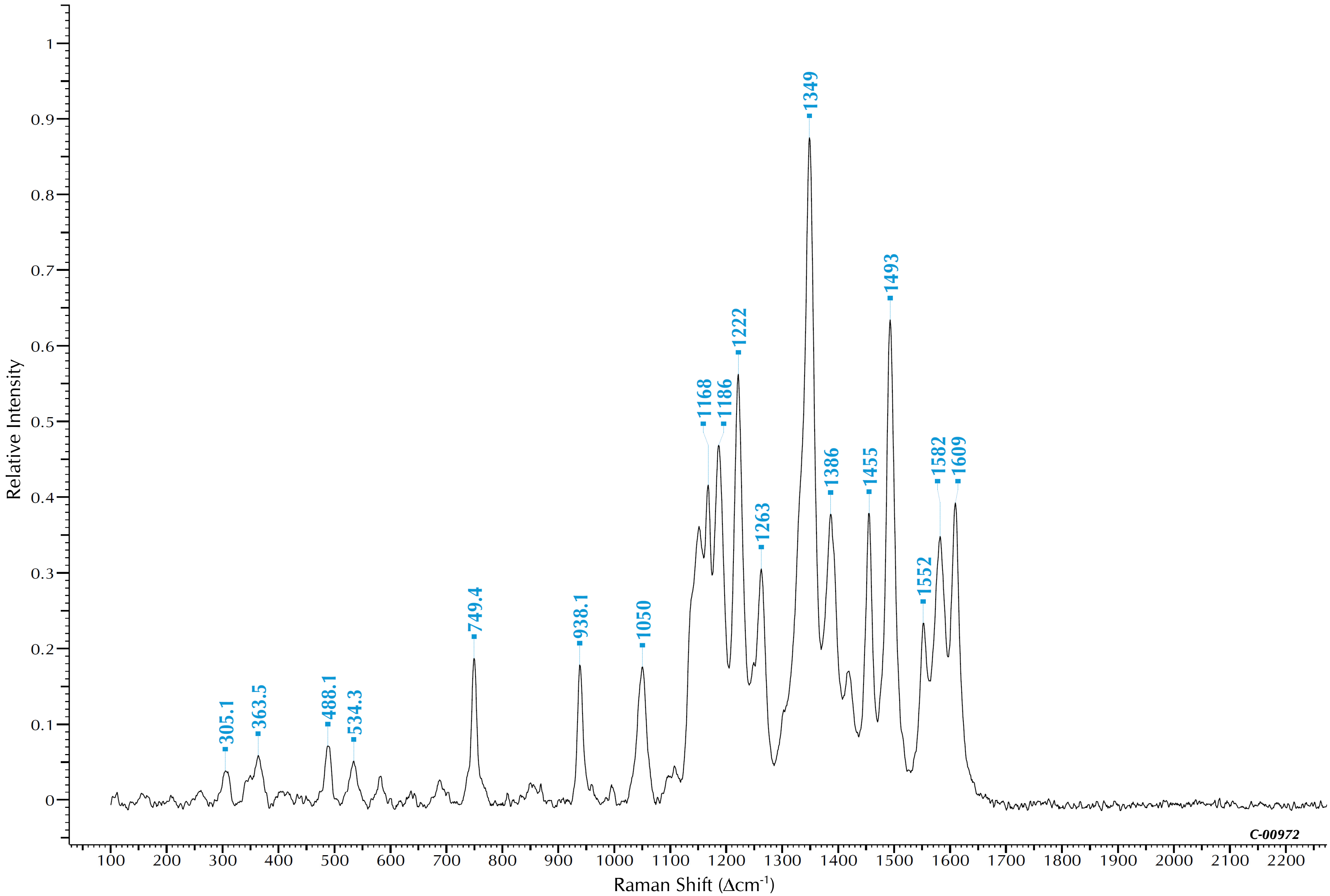
Chemical Category: Organic - Azo - Disazo - Disazopyrazolone
Constitution Number: 21120

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Red 47



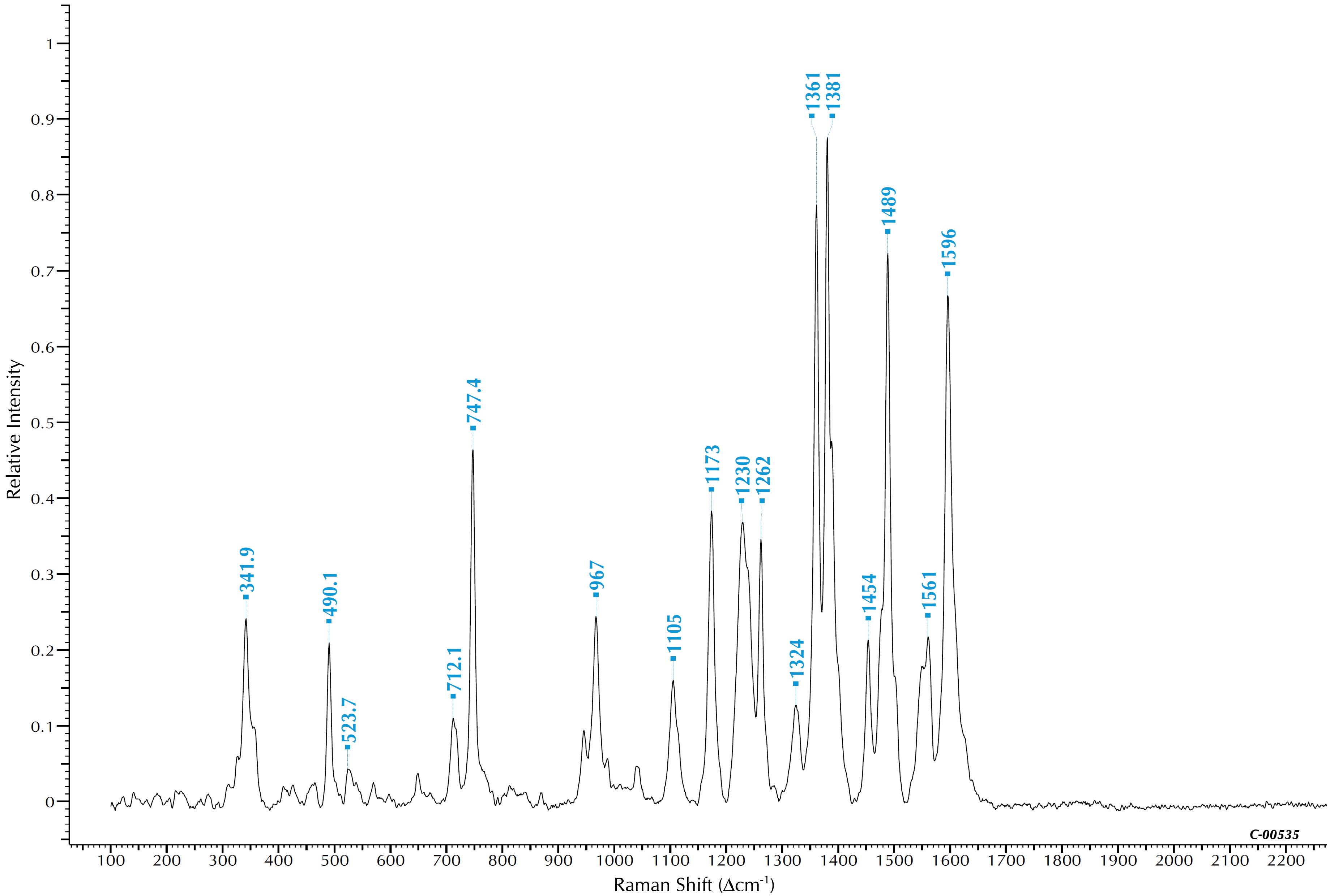
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: Unknown

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 1

Microtrace LLC

C.I. Pigment Red 48:1



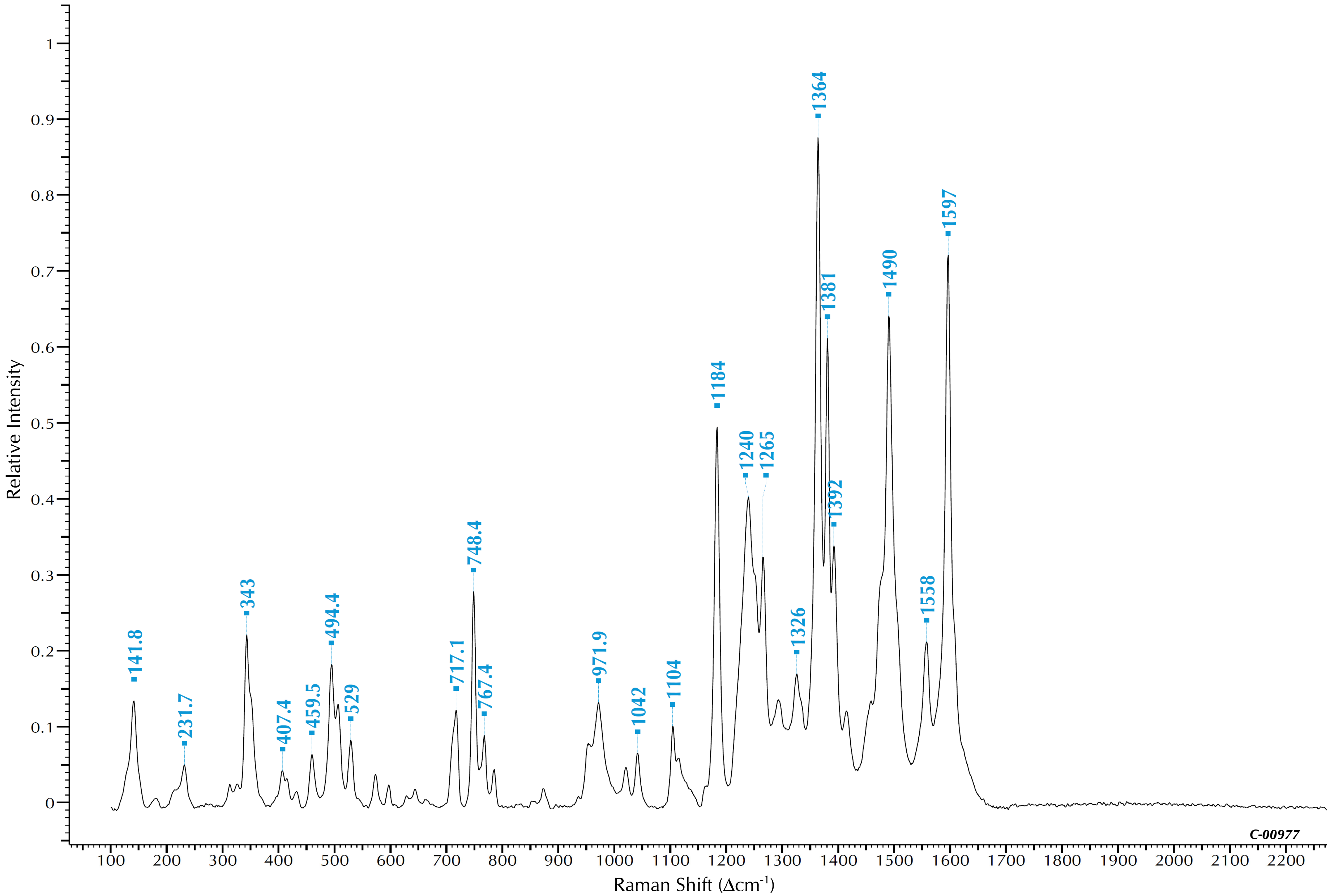
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15865:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 48:2



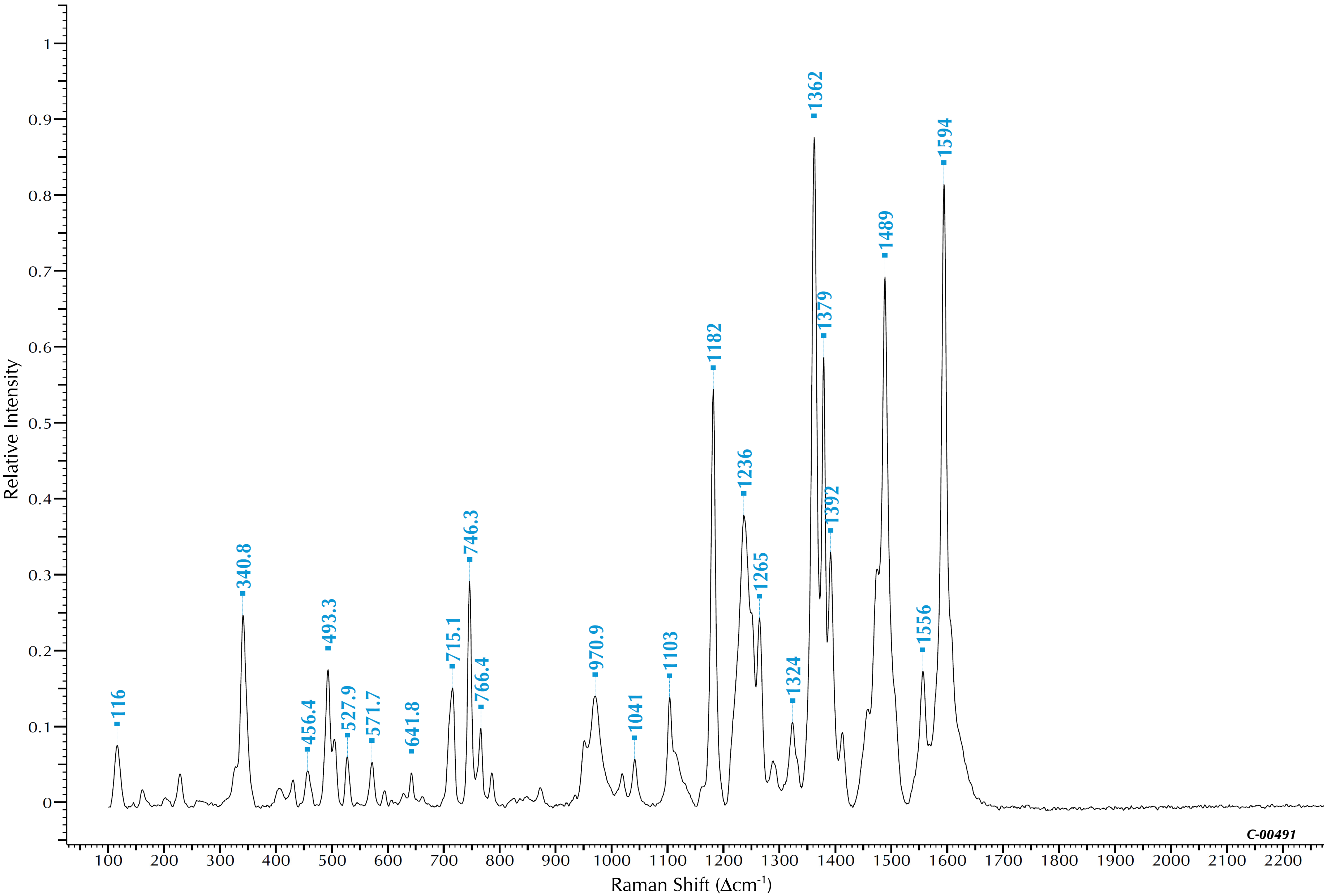
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15865:2

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 48:3



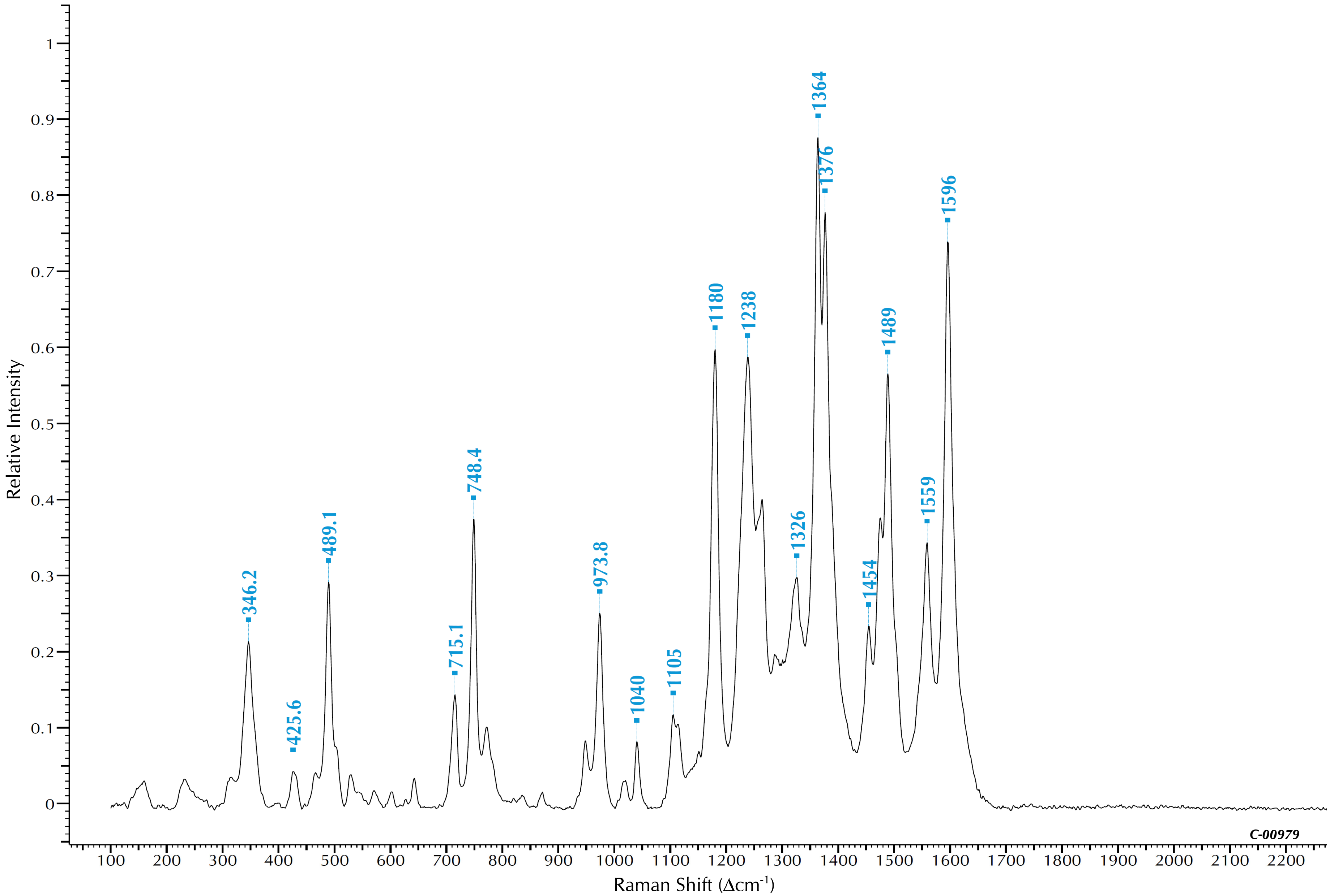
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15865:3

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 48:4



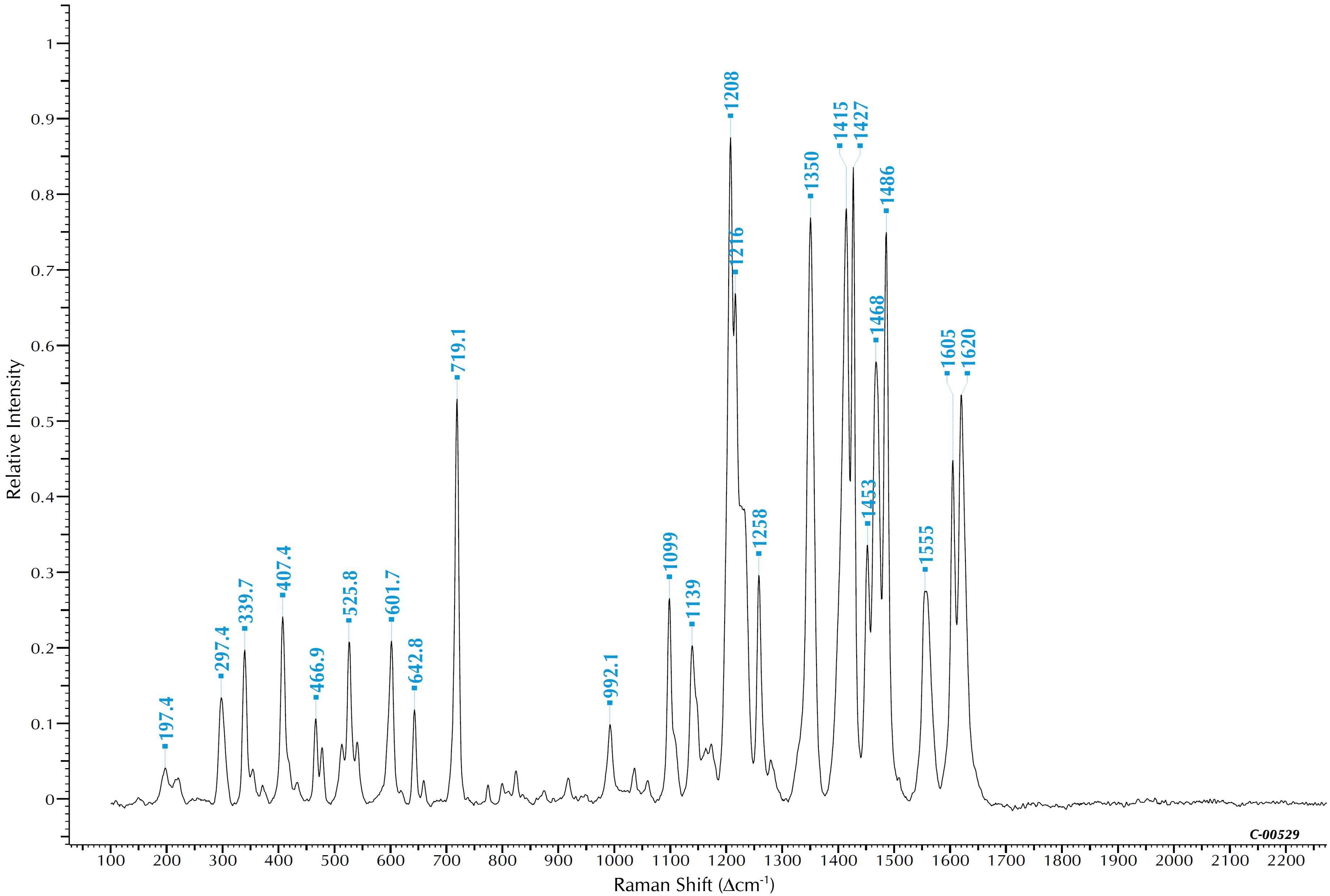
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15865:4

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 49:1



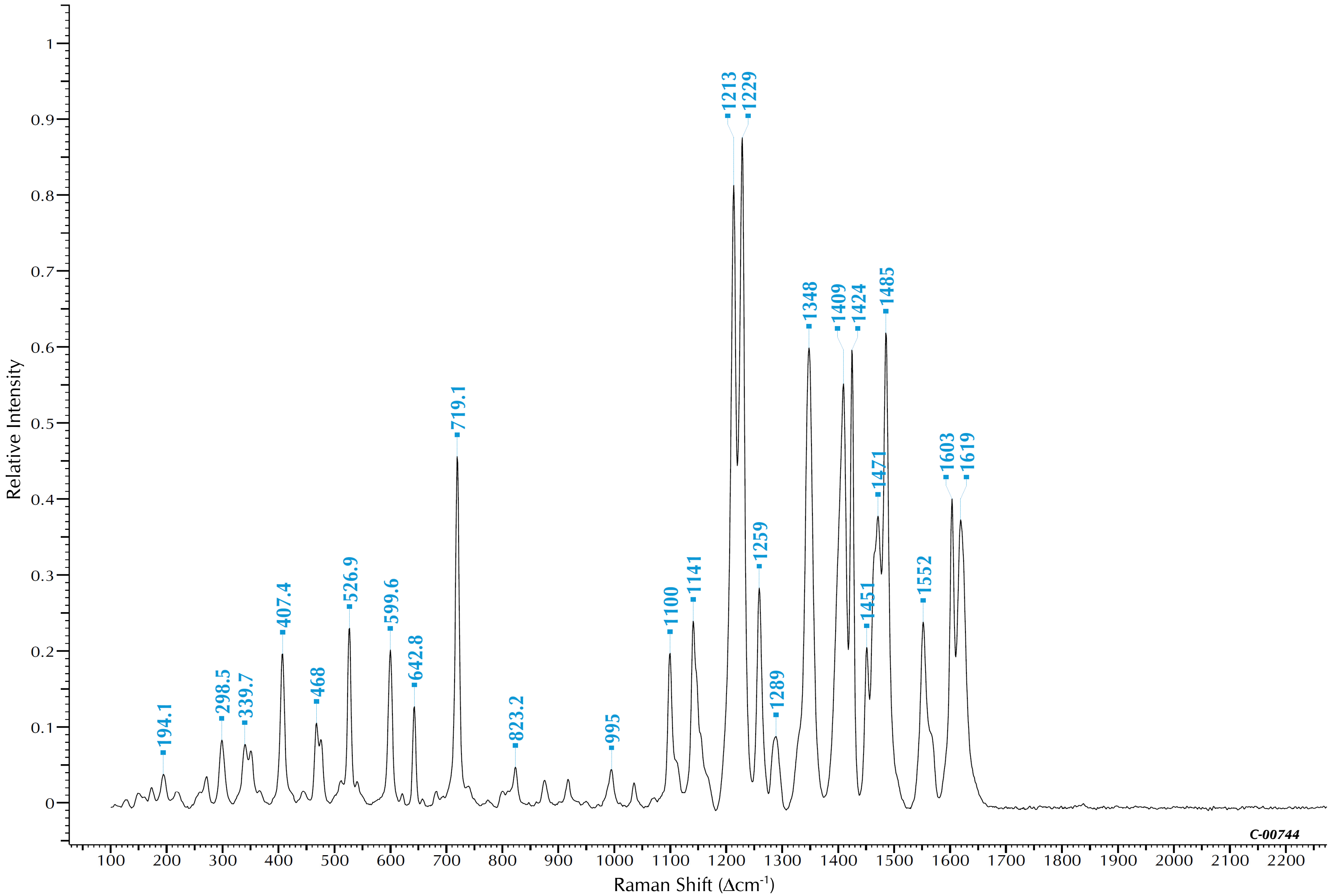
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake
Constitution Number: 15630:1

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 49:2



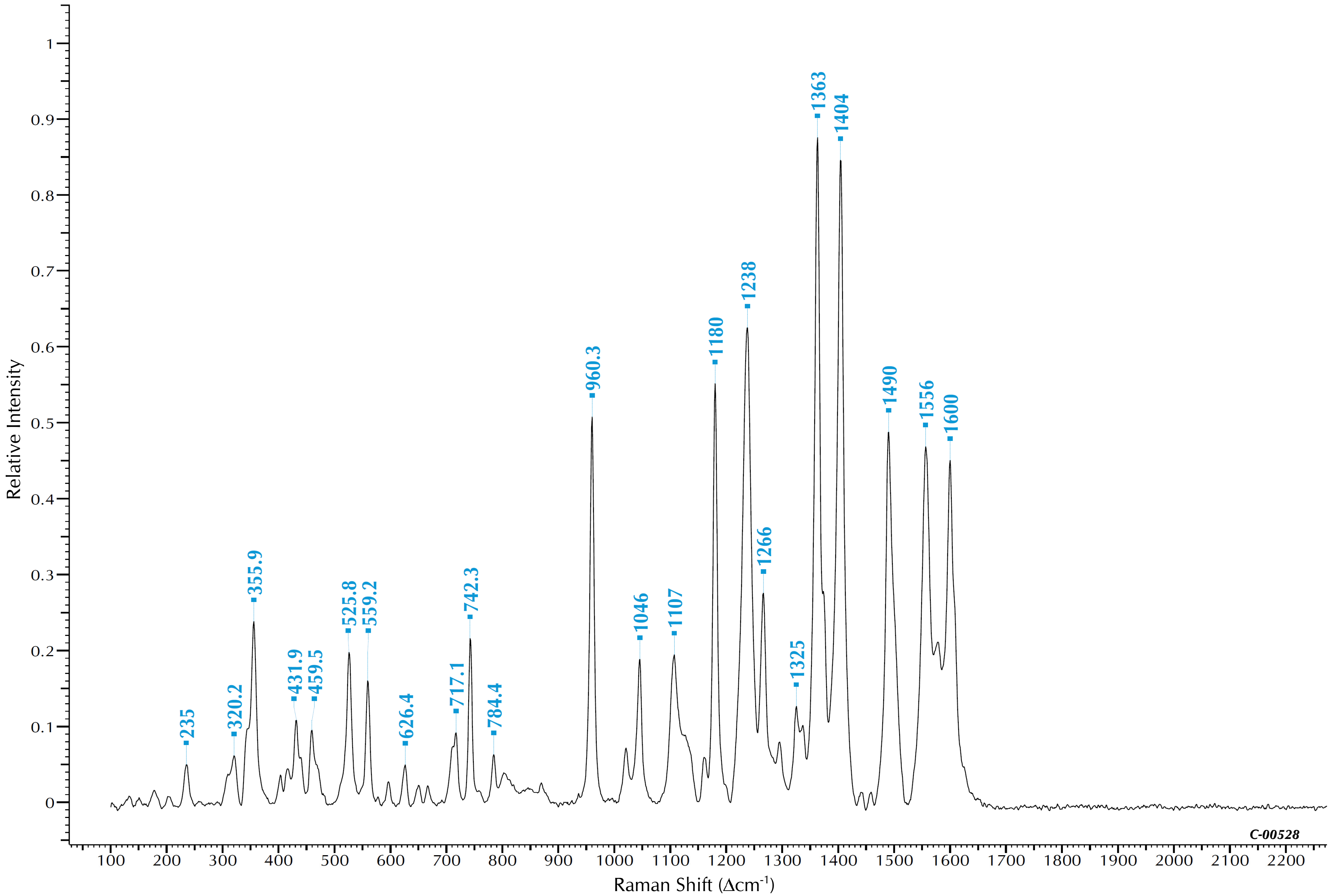
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake
Constitution Number: 15630:2

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 52:1



Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake

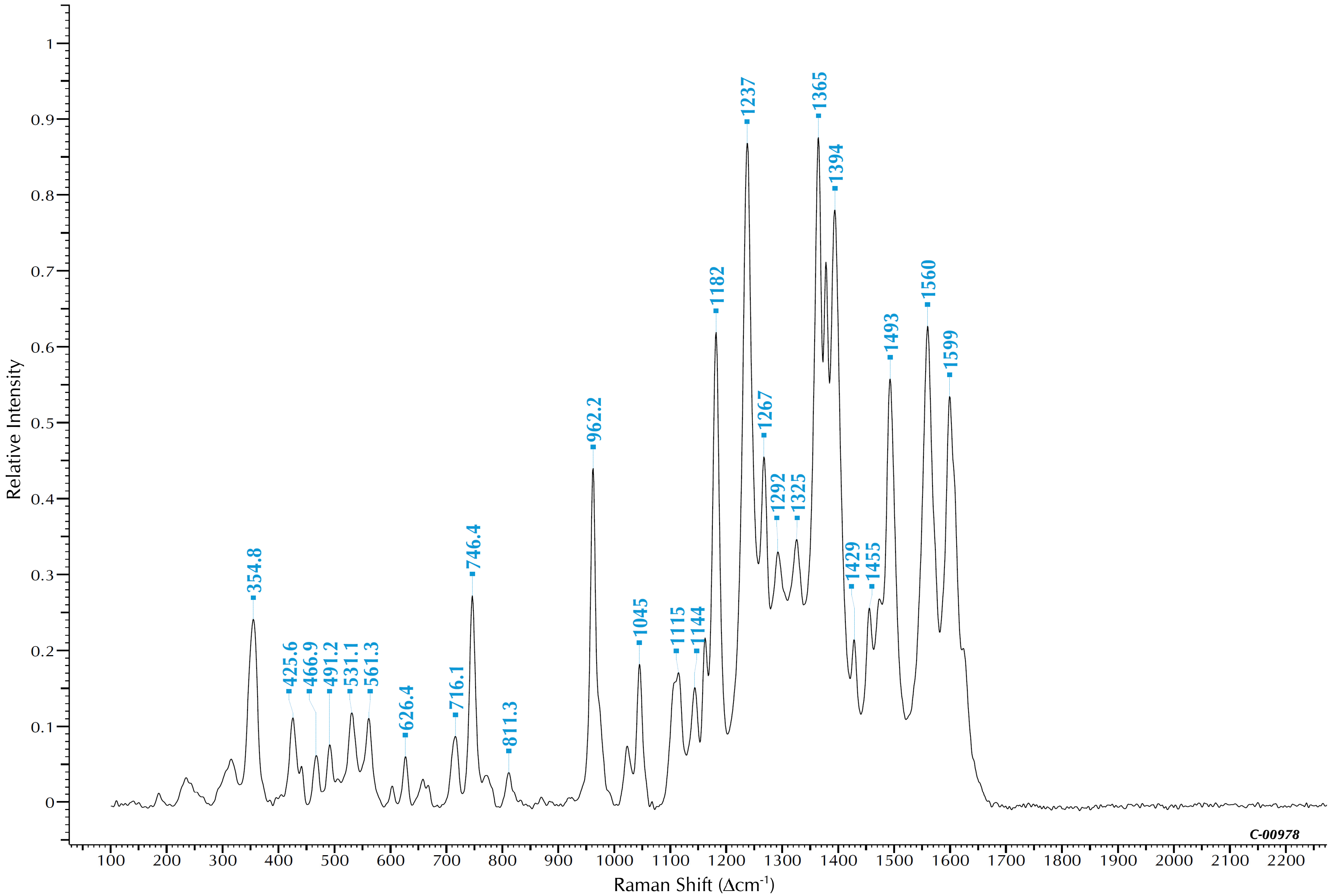
Constitution Number: 15860:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 52:2



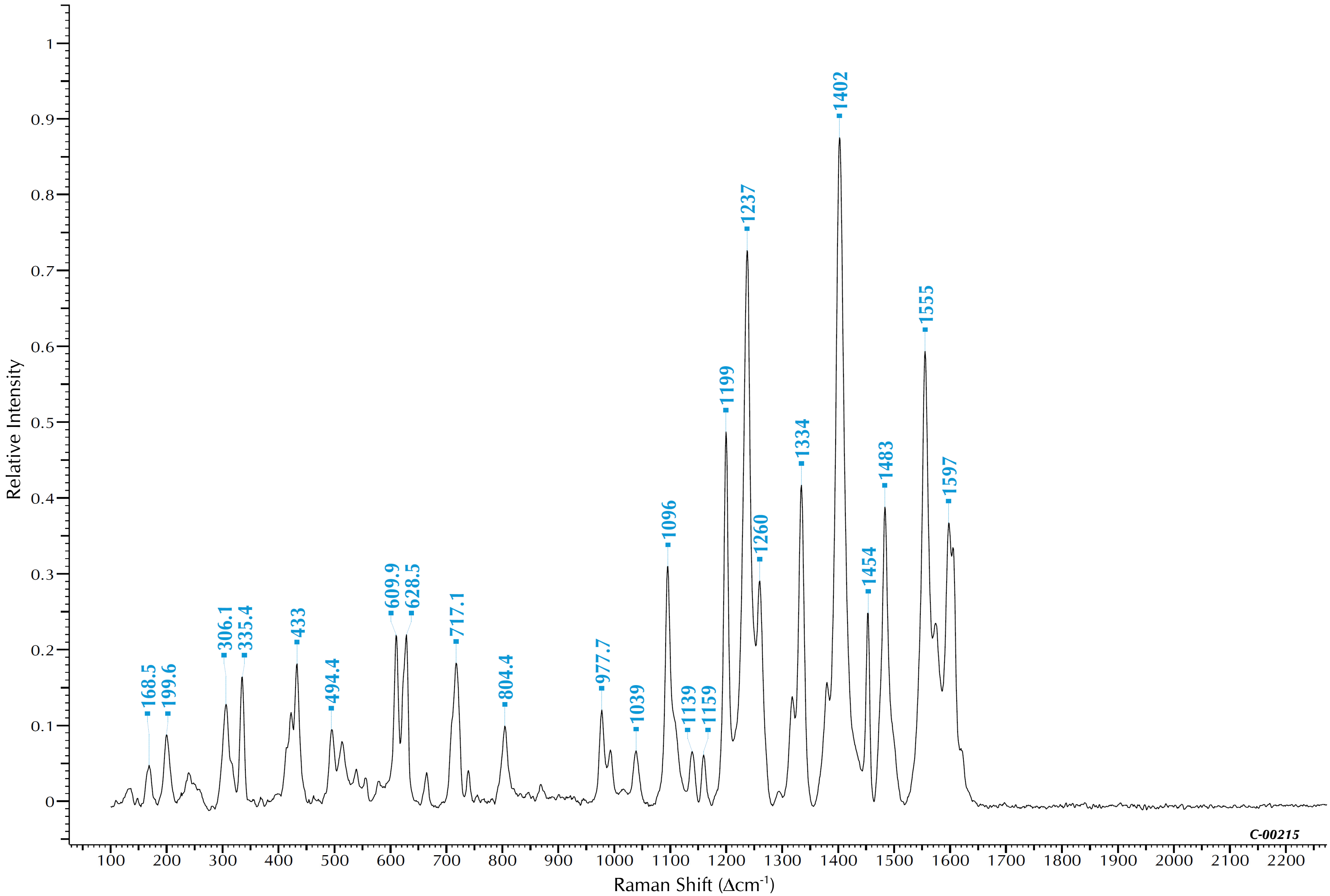
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15860:2

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 53



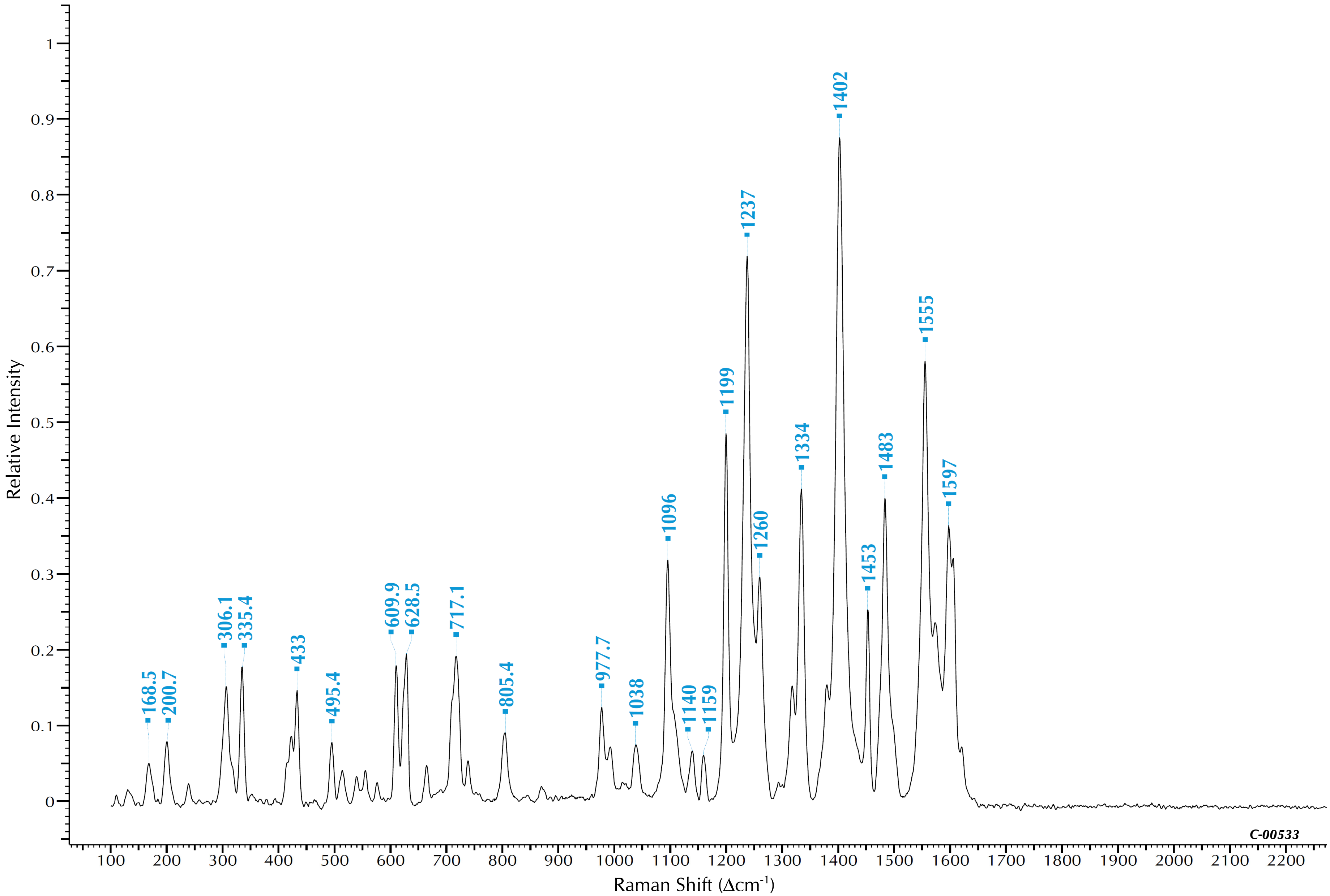
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake
Constitution Number: 15585

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Red 53:1



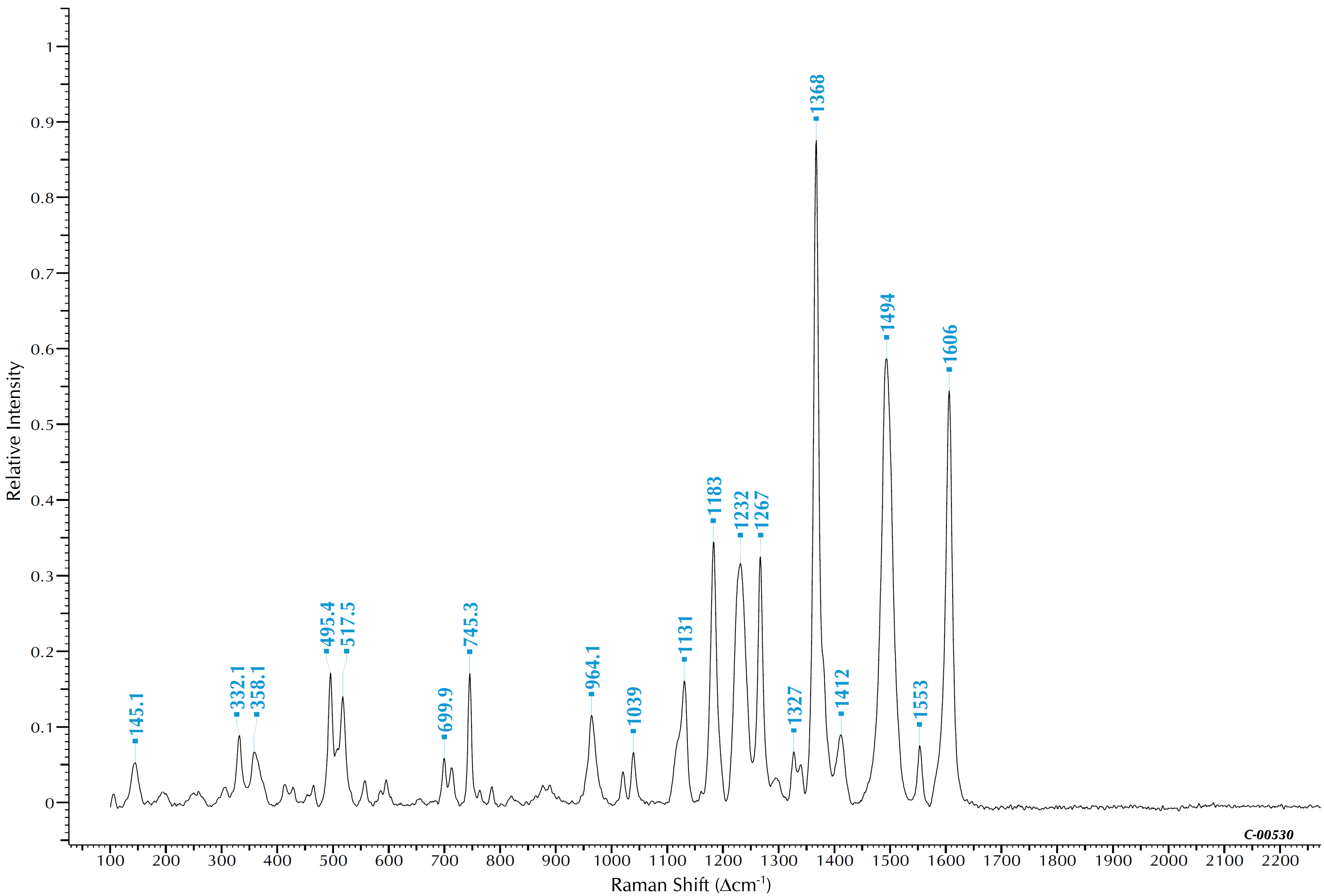
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta-Napthol Lake
Constitution Number: 15585:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 57:1



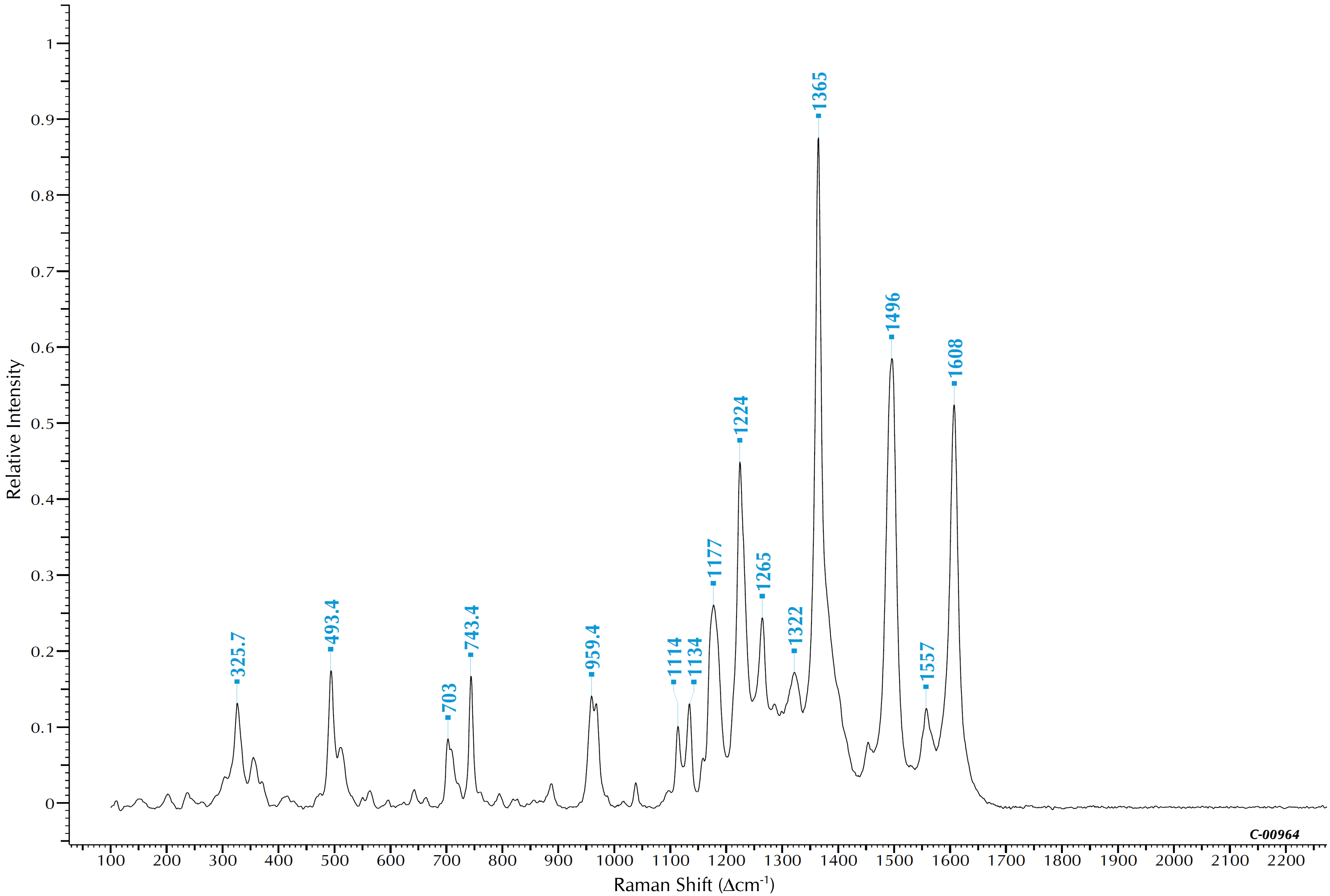
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15850:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Red 57:2



Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake

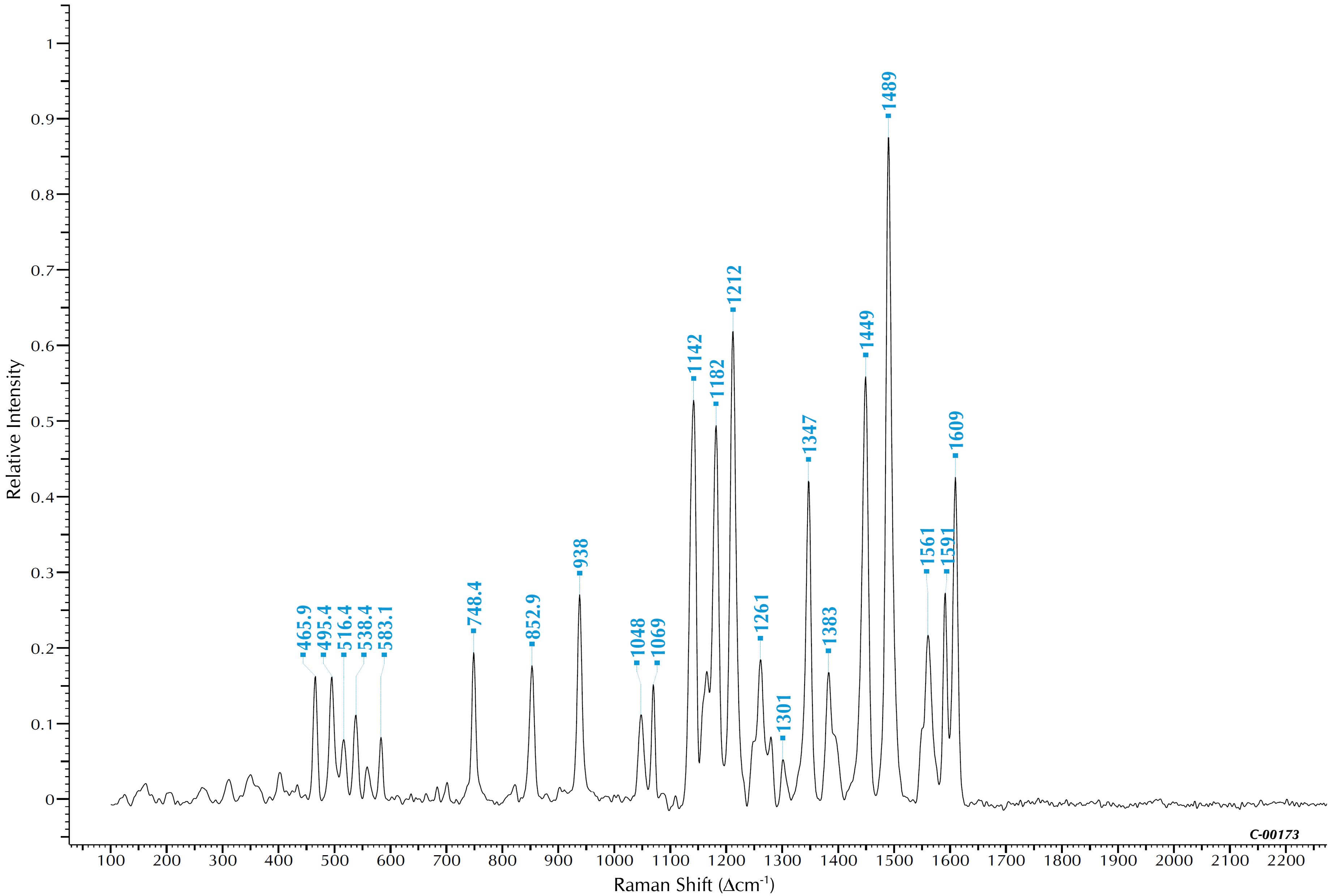
Constitution Number: 15850:2

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 60:1



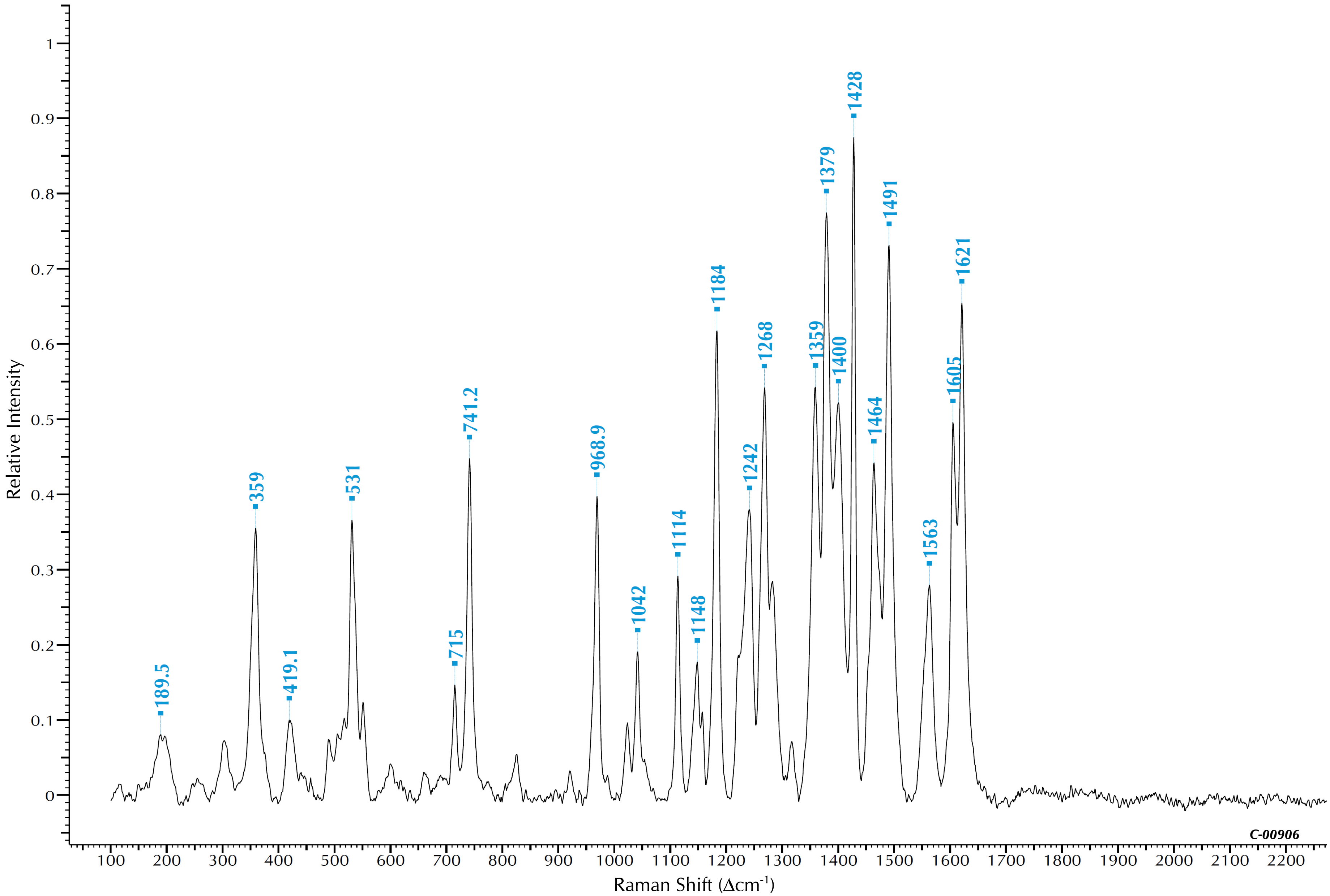
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Naphthalene Sulfonic Acid Lakes
Constitution Number: 16105:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 63:1



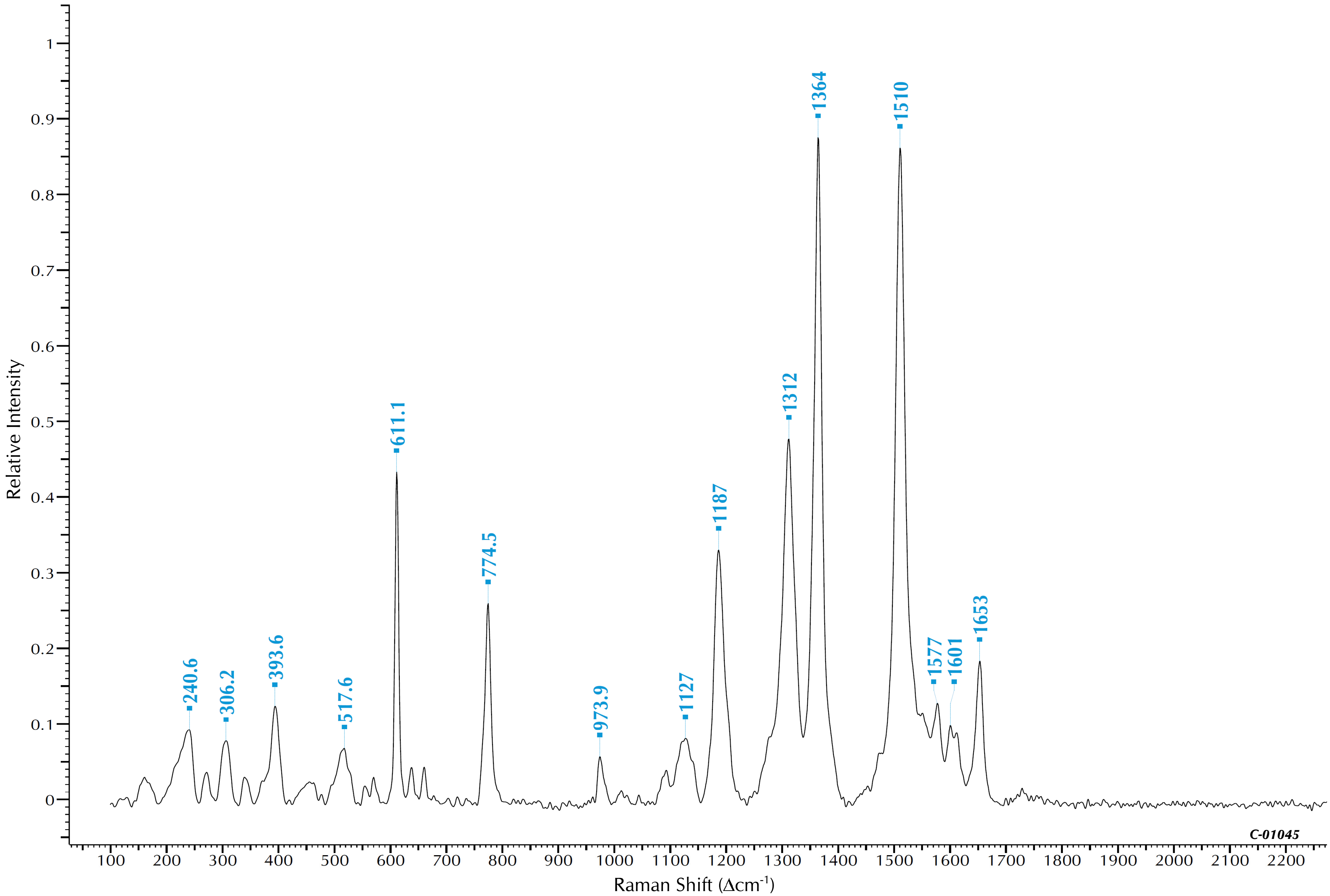
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15880:1

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Red 81



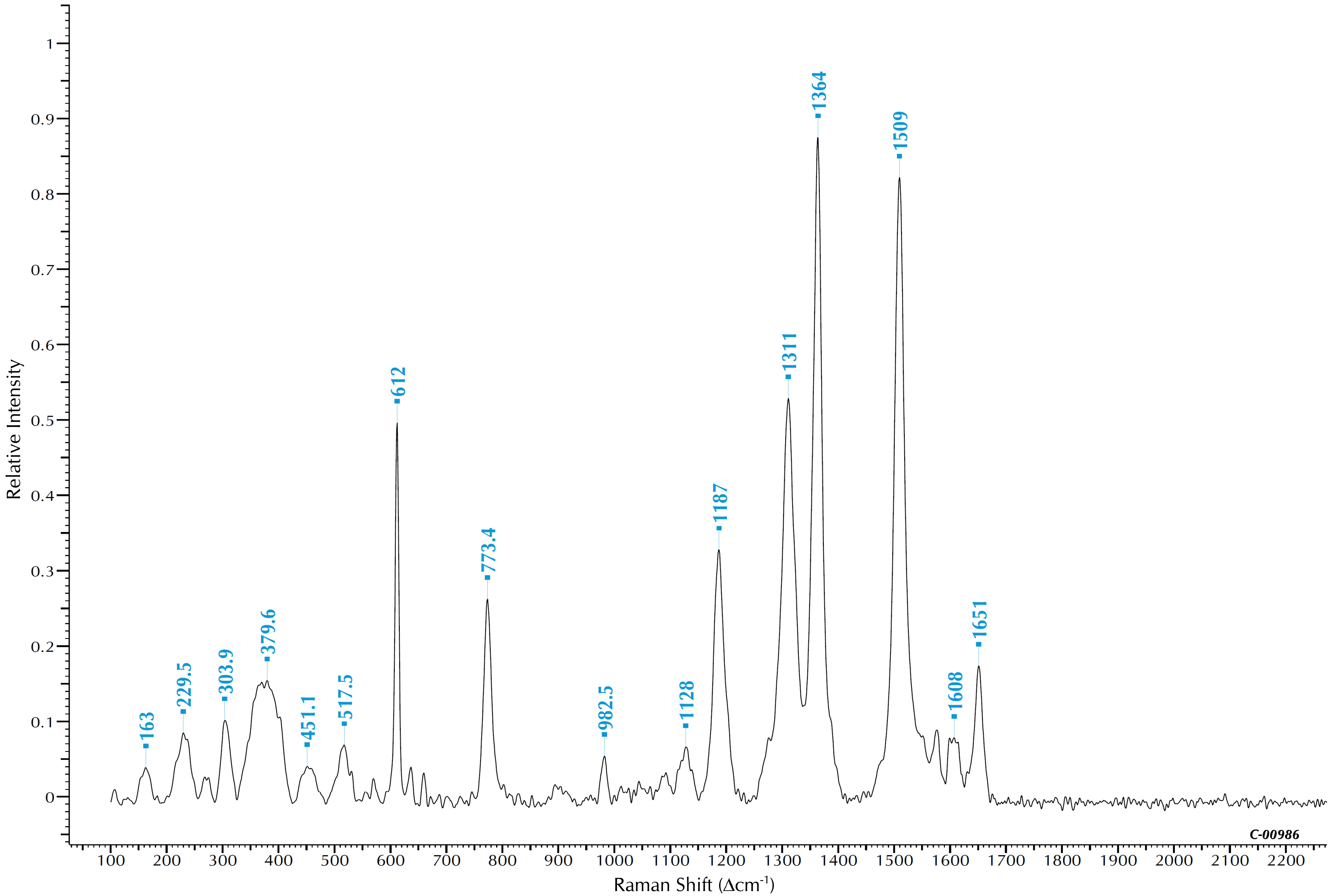
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45160:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 81:1



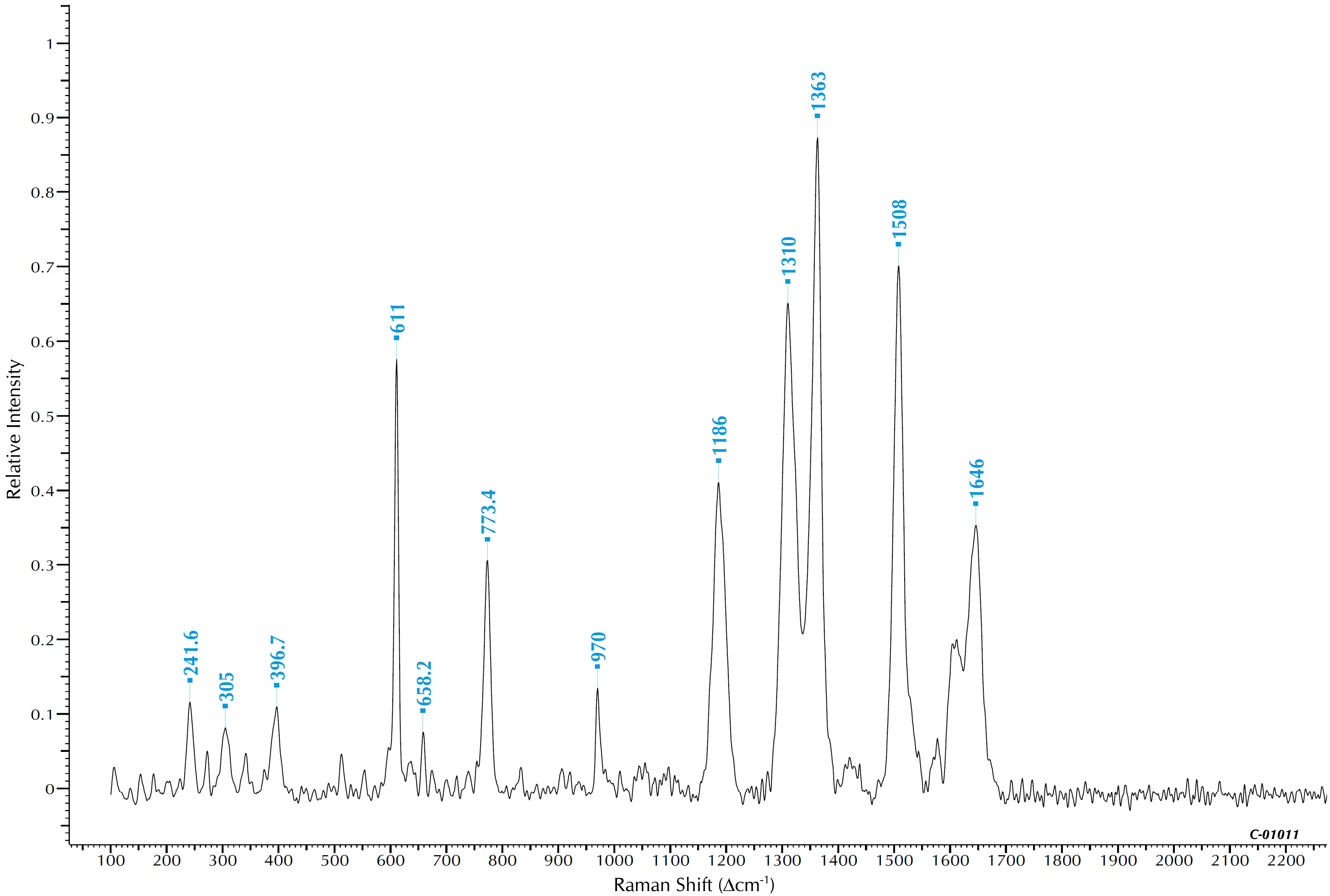
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45160:3

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 81:3



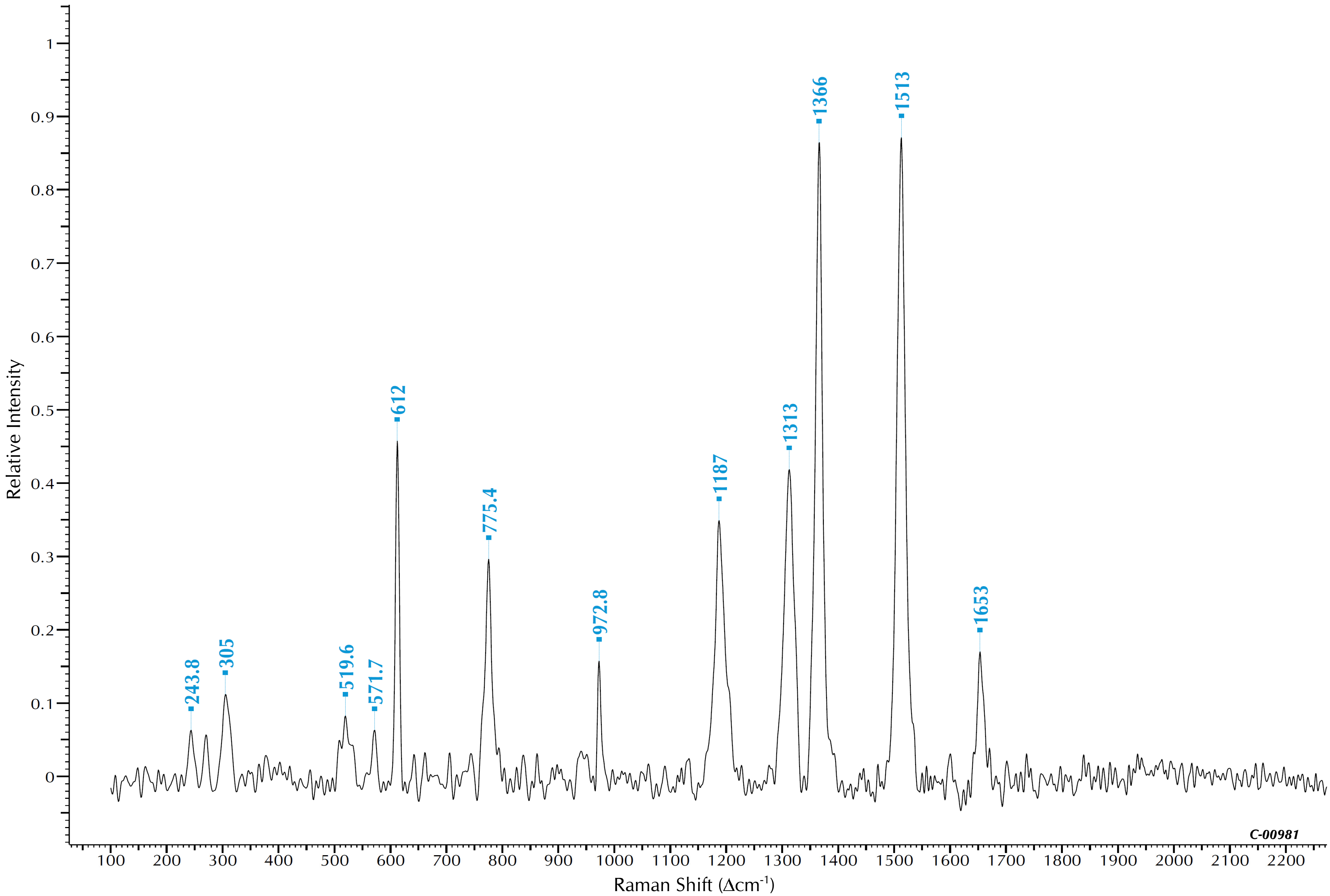
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45161:2

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 81:5



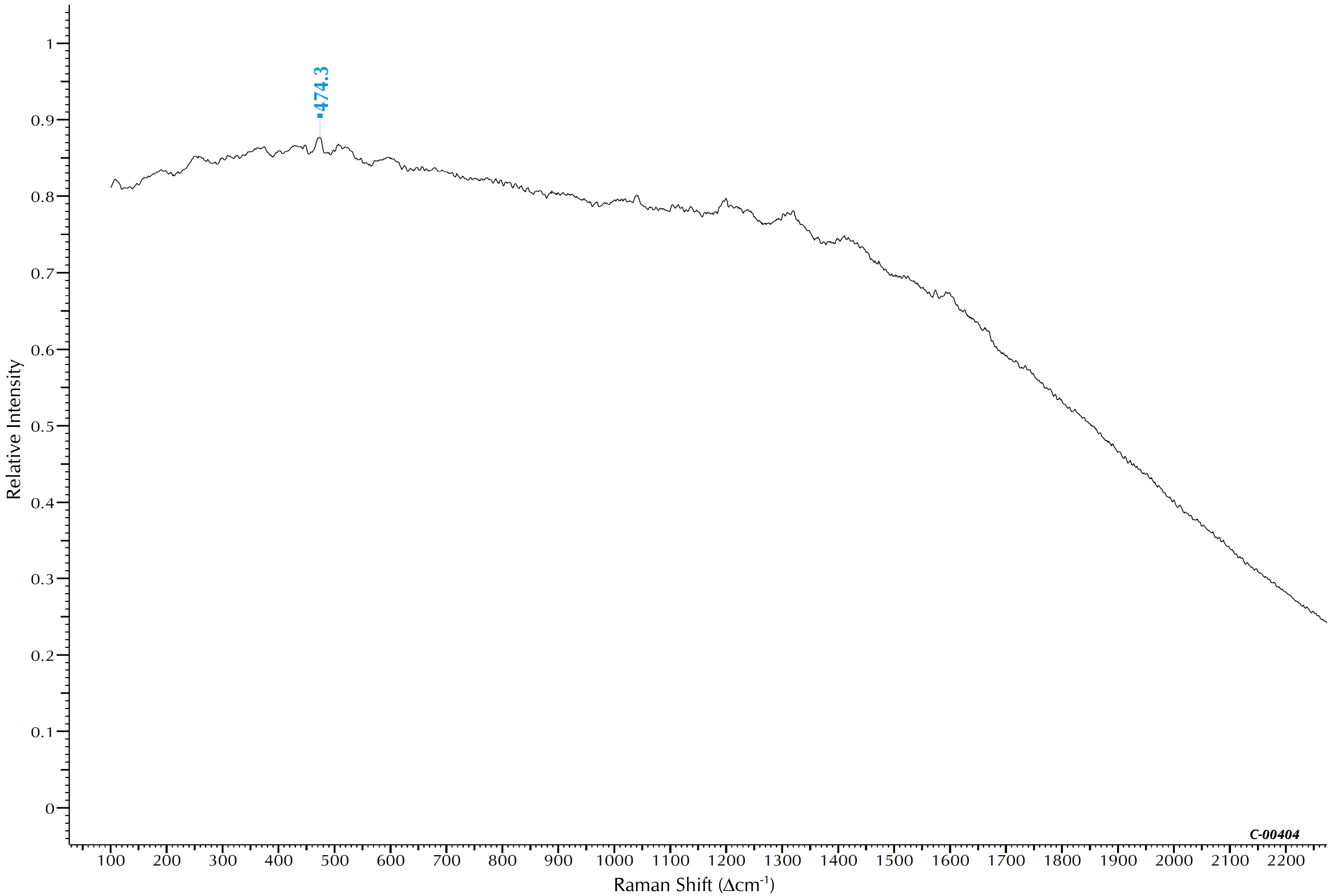
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45160:4

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 83



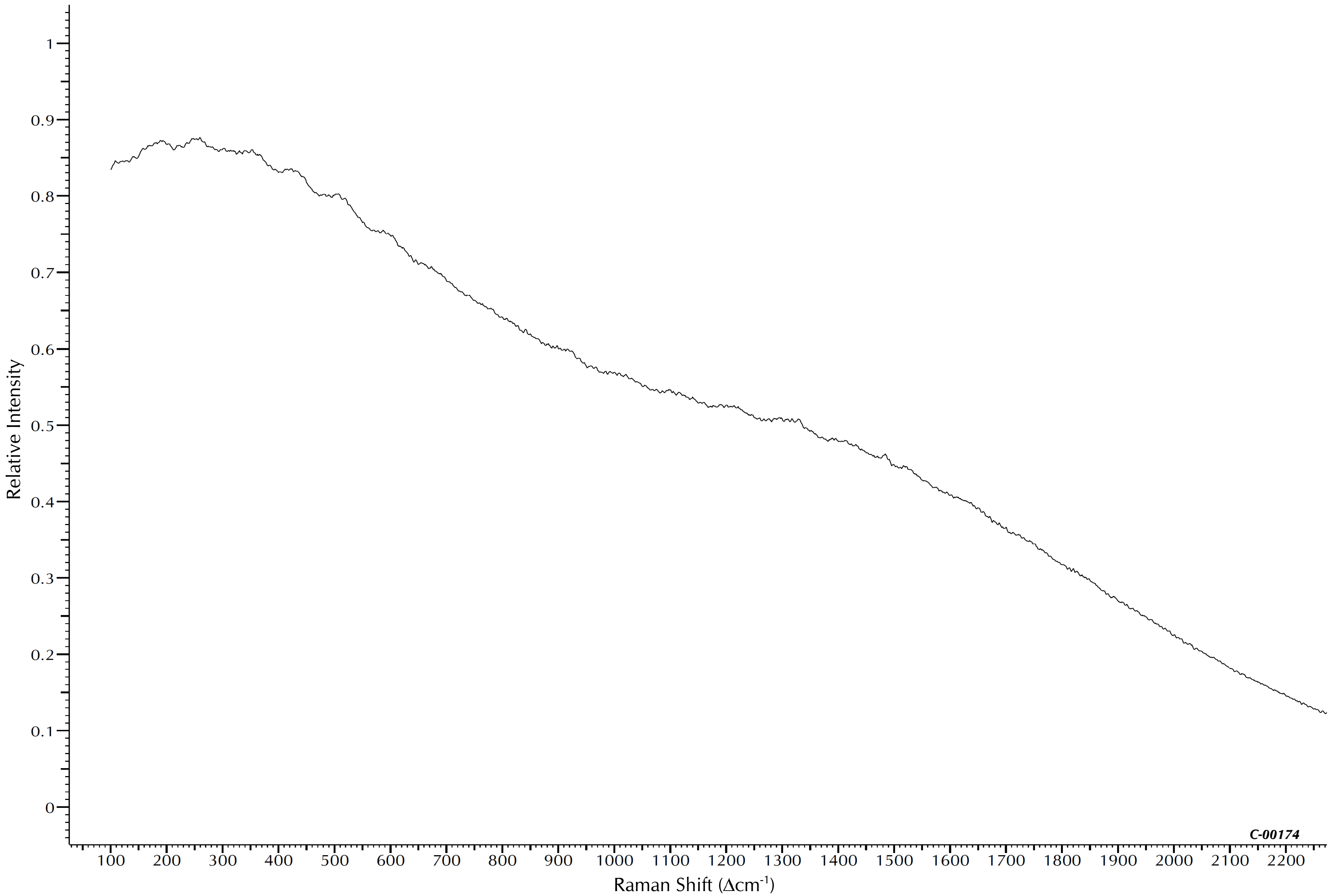
Chemical Category: Organic - Polycyclic - Hydroxyanthraquinone
Constitution Number: 56000

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 83:1



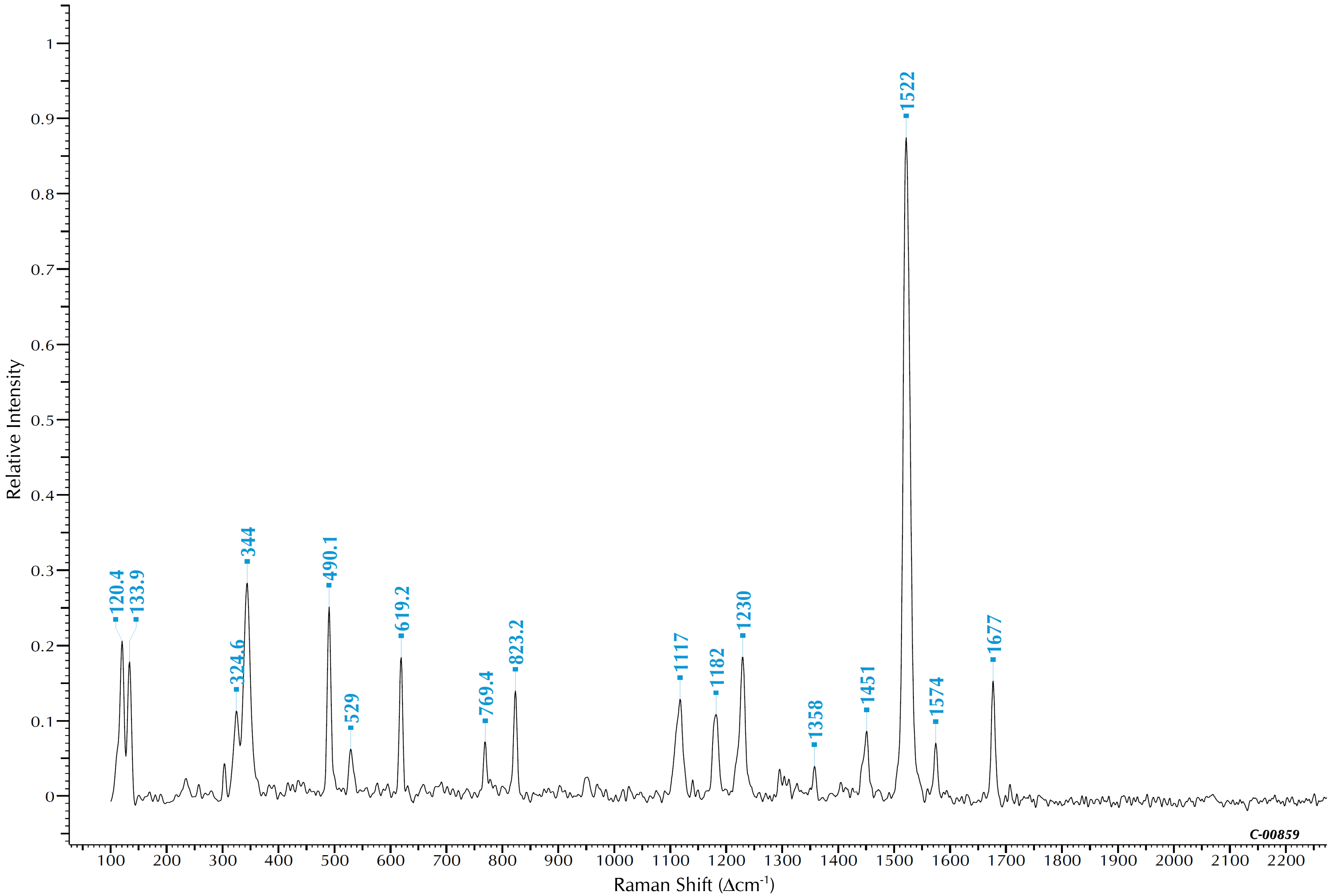
Chemical Category: Organic - Polycyclic - Hydroxyanthraquinone
Constitution Number: 58000:1

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Red 88



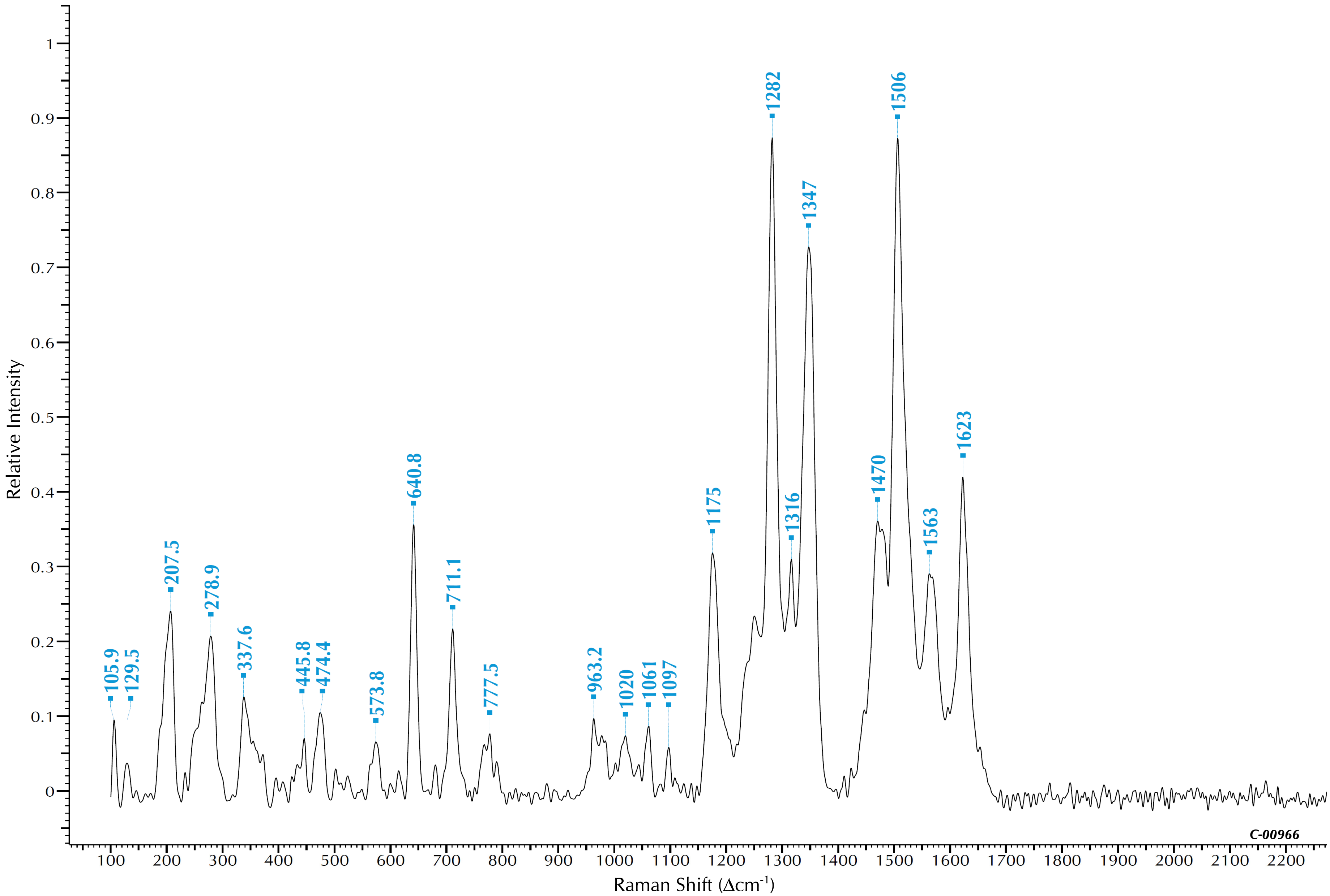
Chemical Category: Organic - Polycyclic - Thioindigo - Substituted
Constitution Number: 73312

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 2

Microtrace LLC

C.I. Pigment Red 90:1



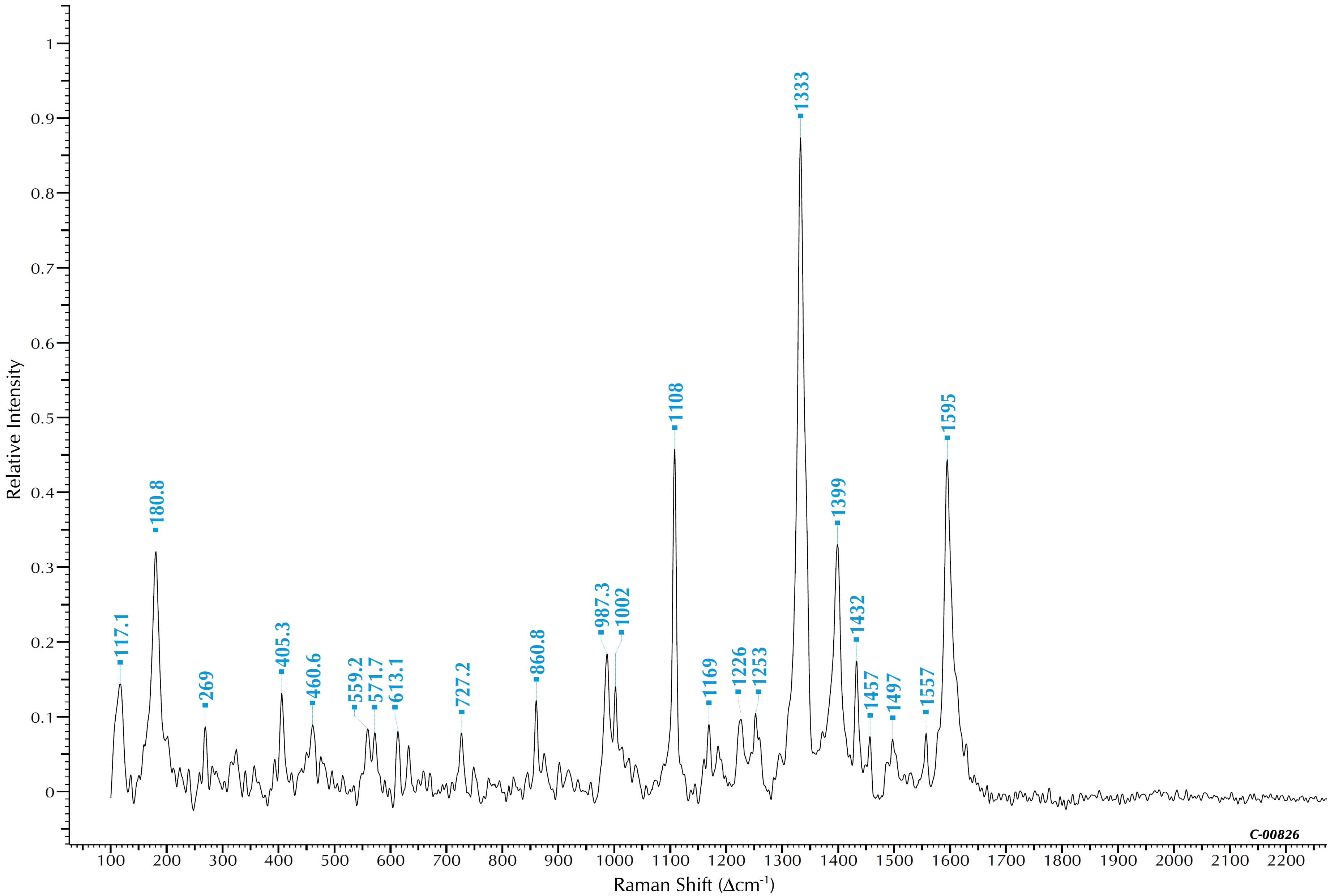
Chemical Category: Organic - Other
Constitution Number: 45380:3

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 101



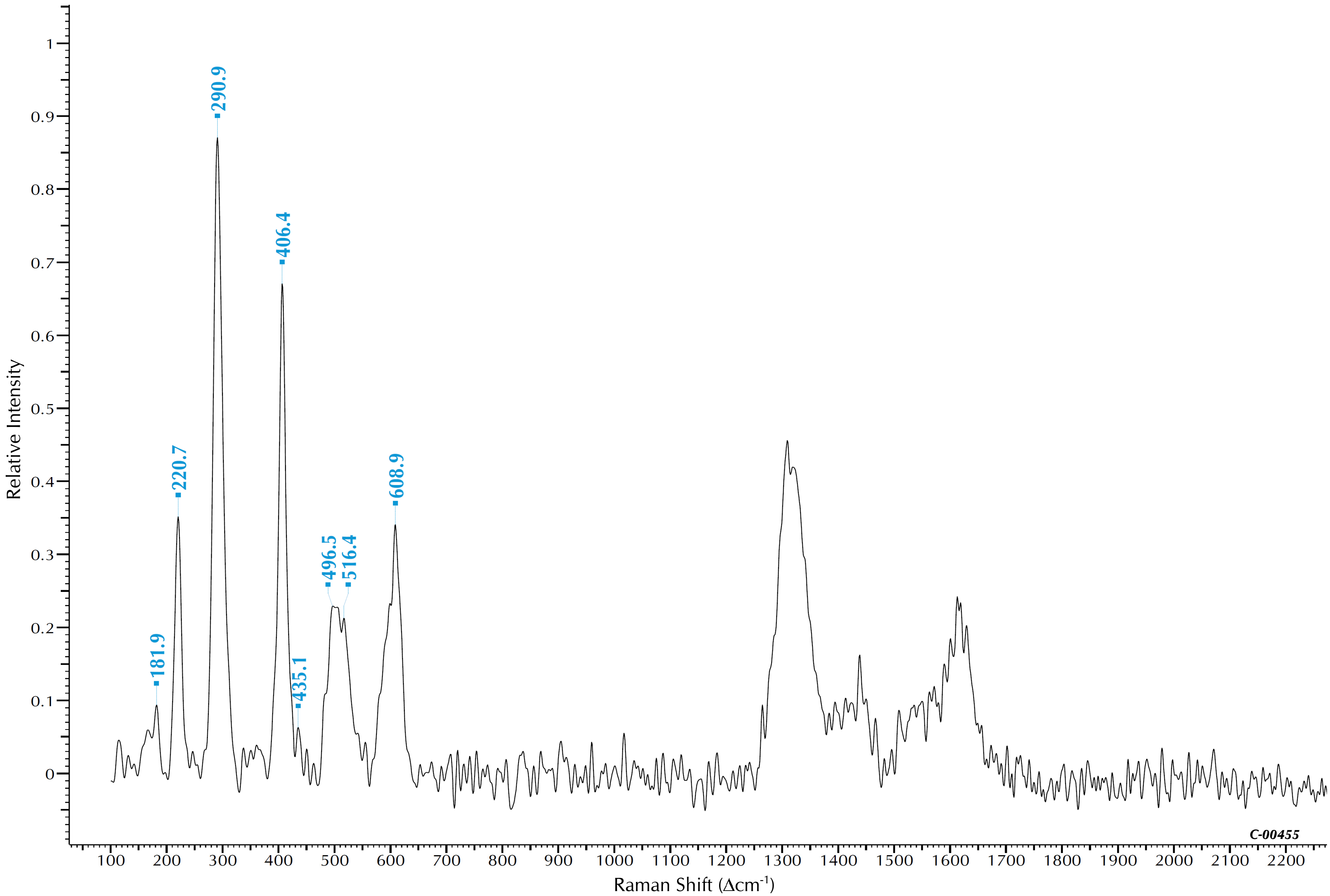
Chemical Category: Inorganic - Oxide
Constitution Number: 77015 77491, 77538

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 101:1



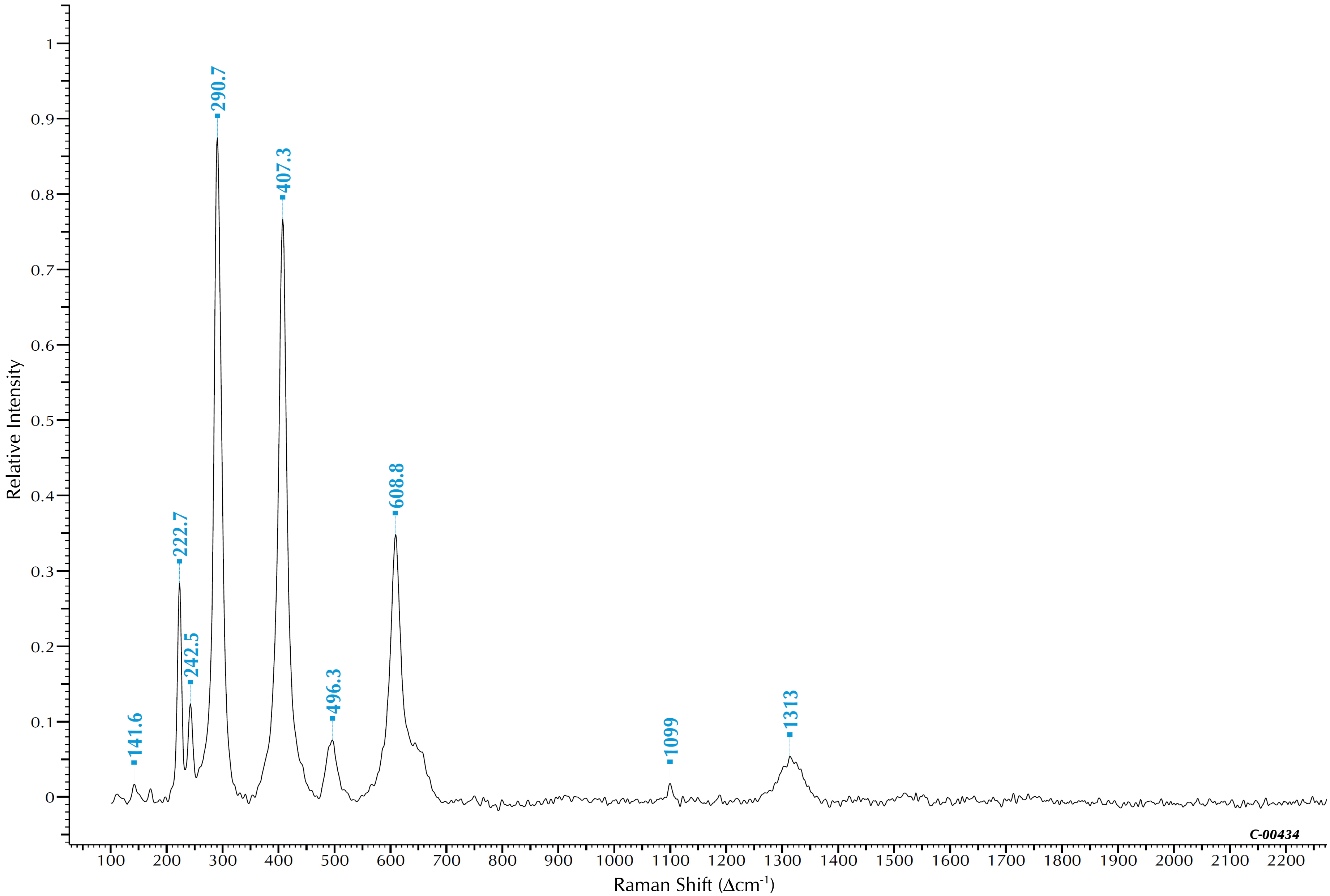
Chemical Category: Inorganic - Oxide
Constitution Number: 77015

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 8

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 4

Microtrace LLC

C.I. Pigment Red 102



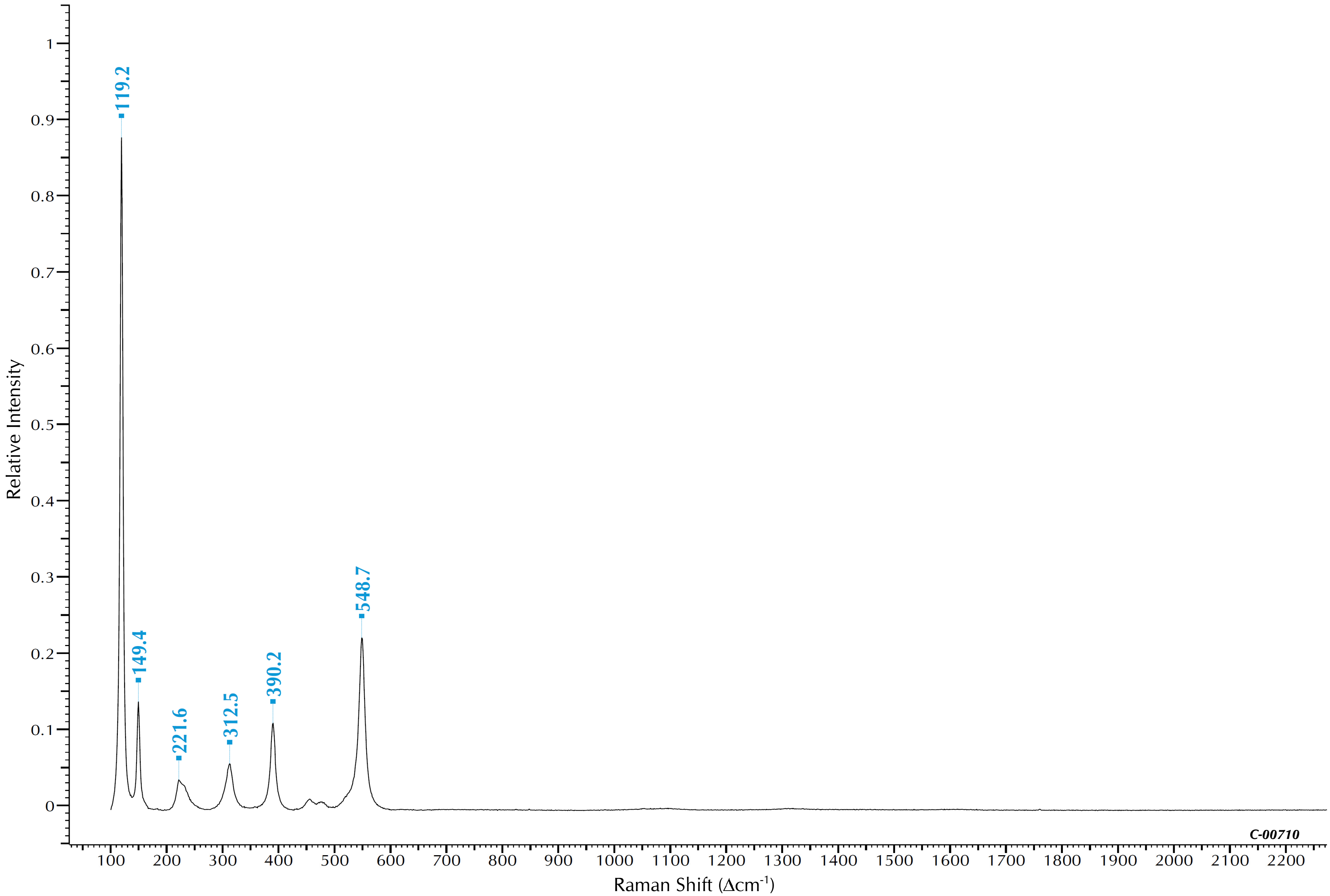
Chemical Category: Inorganic - Oxide
Constitution Number: 77492

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 105



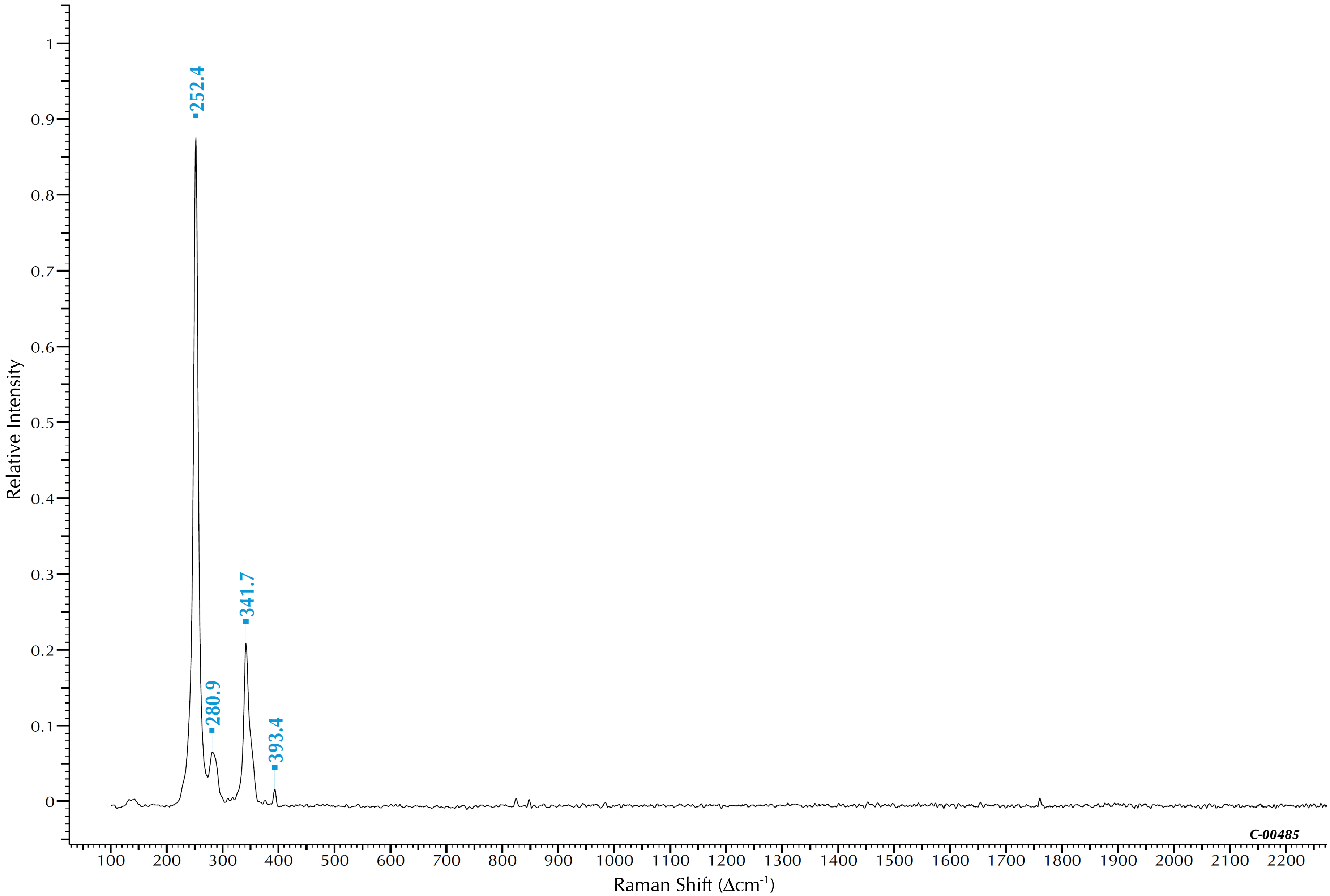
Chemical Category: Inorganic - Oxide
Constitution Number: 77578

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 106



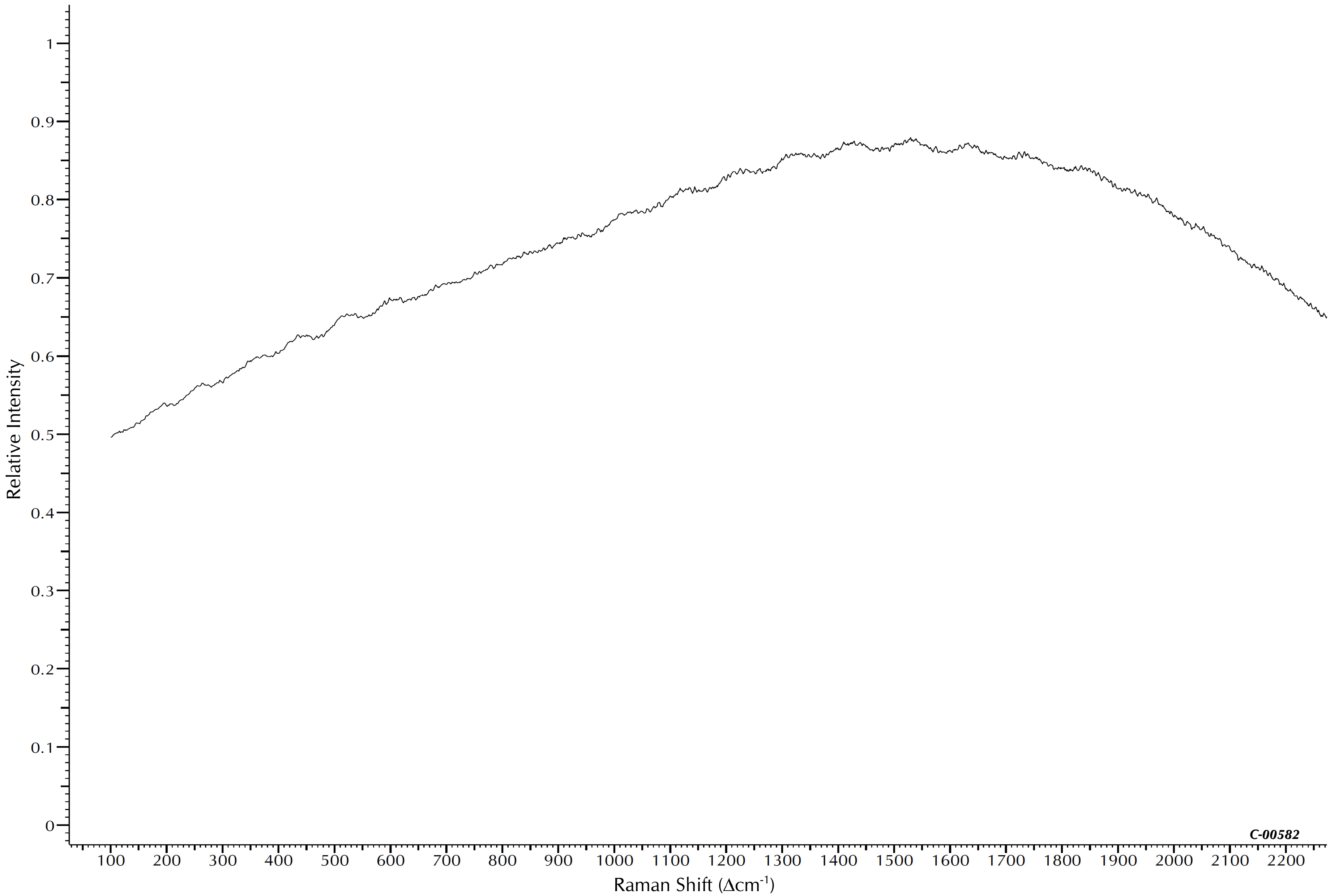
Chemical Category: Inorganic - Sulfide
Constitution Number: 77766

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.01
Quality Index 4

Microtrace LLC

C.I. Pigment Red 108



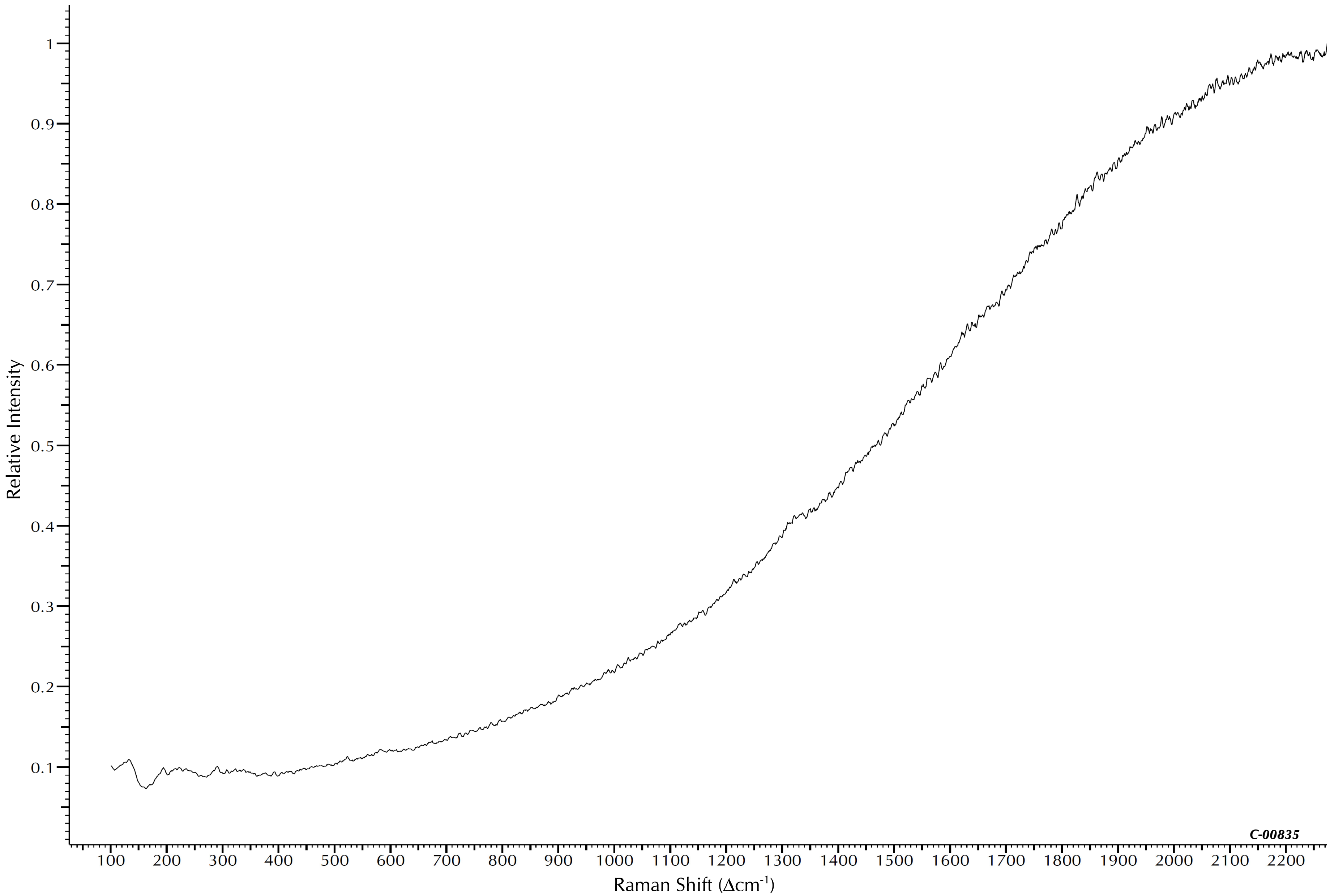
Chemical Category: Inorganic - Sulfate
Constitution Number: 77202 77196

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 4

Microtrace LLC

C.I. Pigment Red 108:1



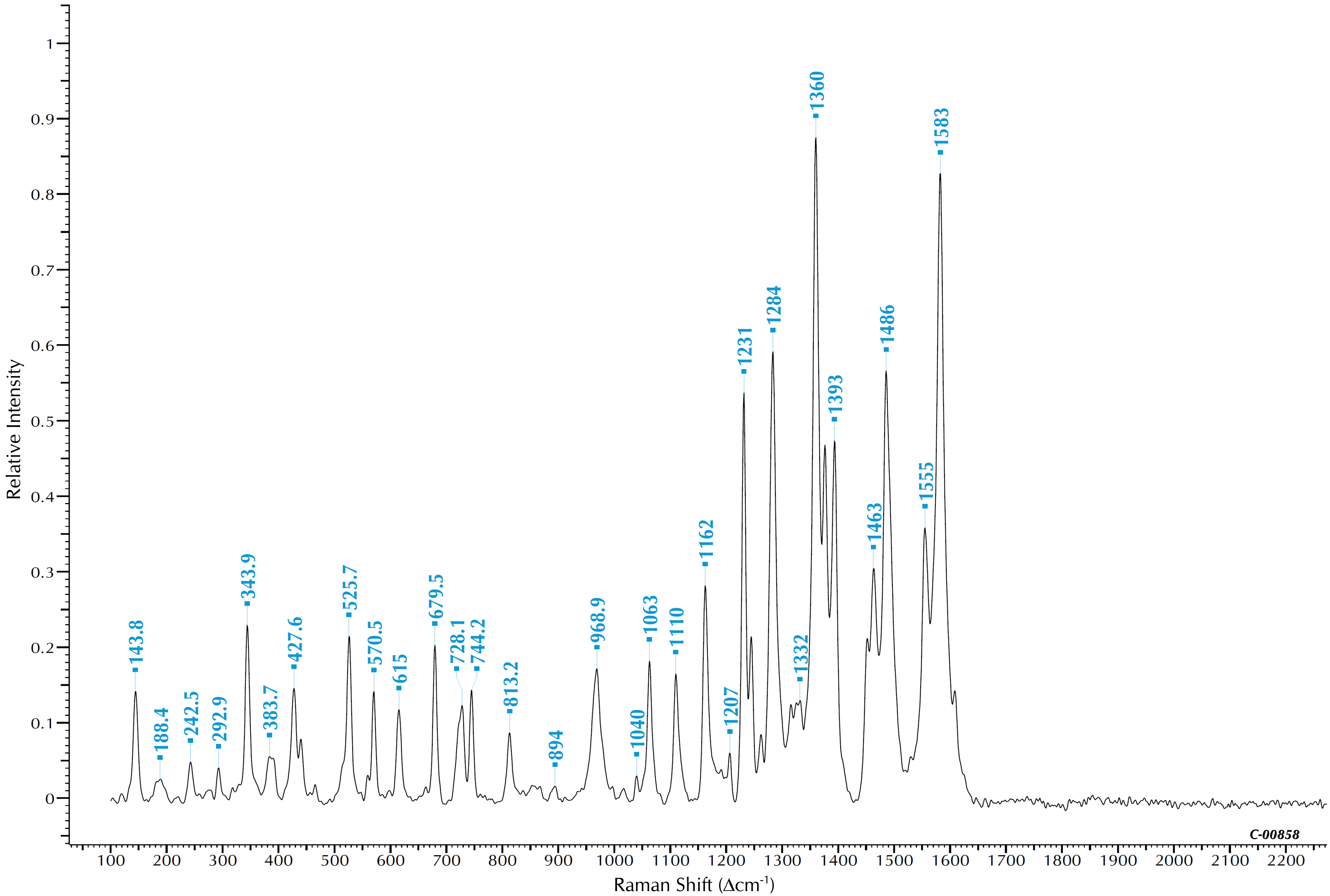
Chemical Category: Inorganic - Sulfate
Constitution Number: 77202:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Red 112



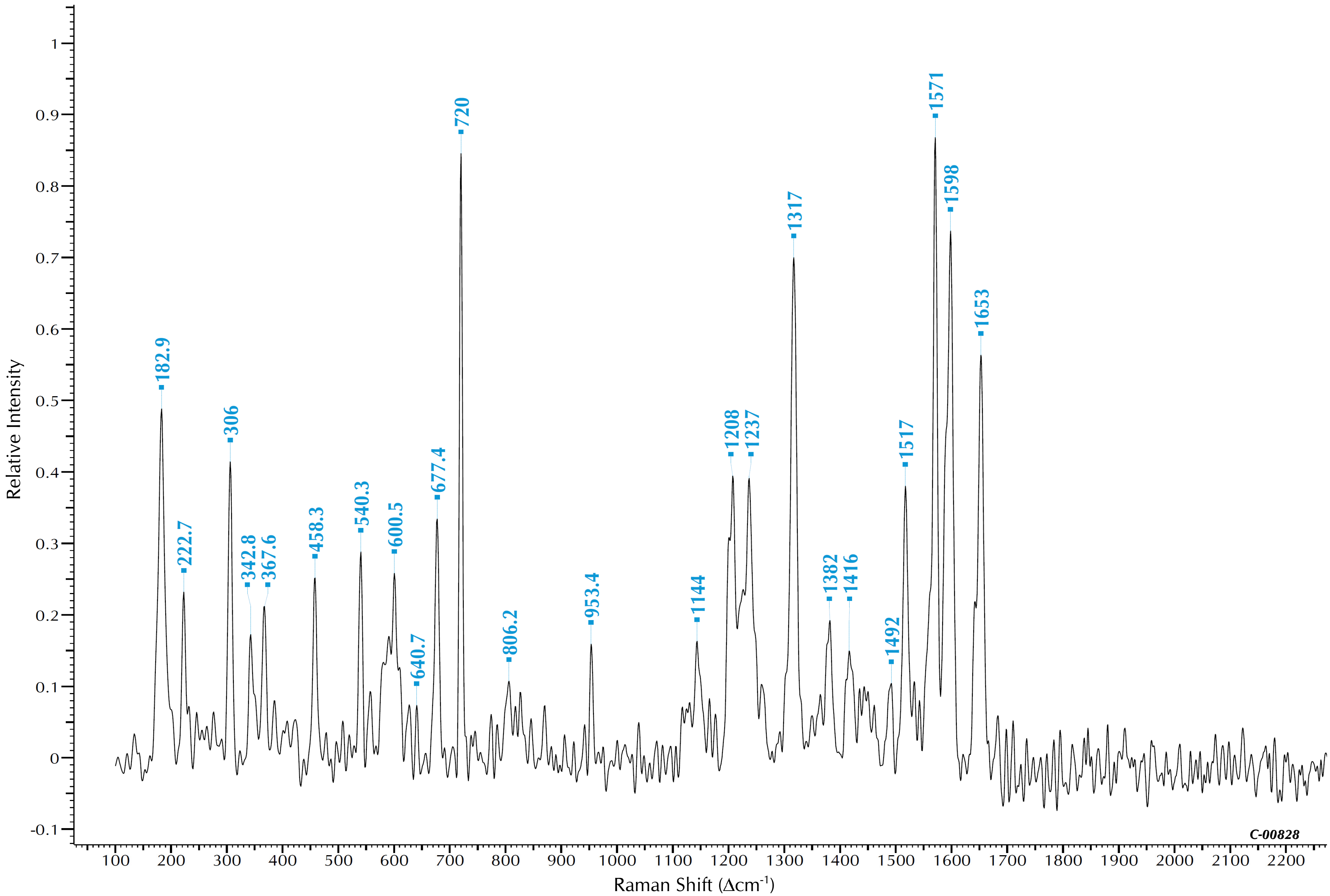
Chemical Category: Organic - Azo - Naphthol AS - Group 1
Constitution Number: 12370

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 122



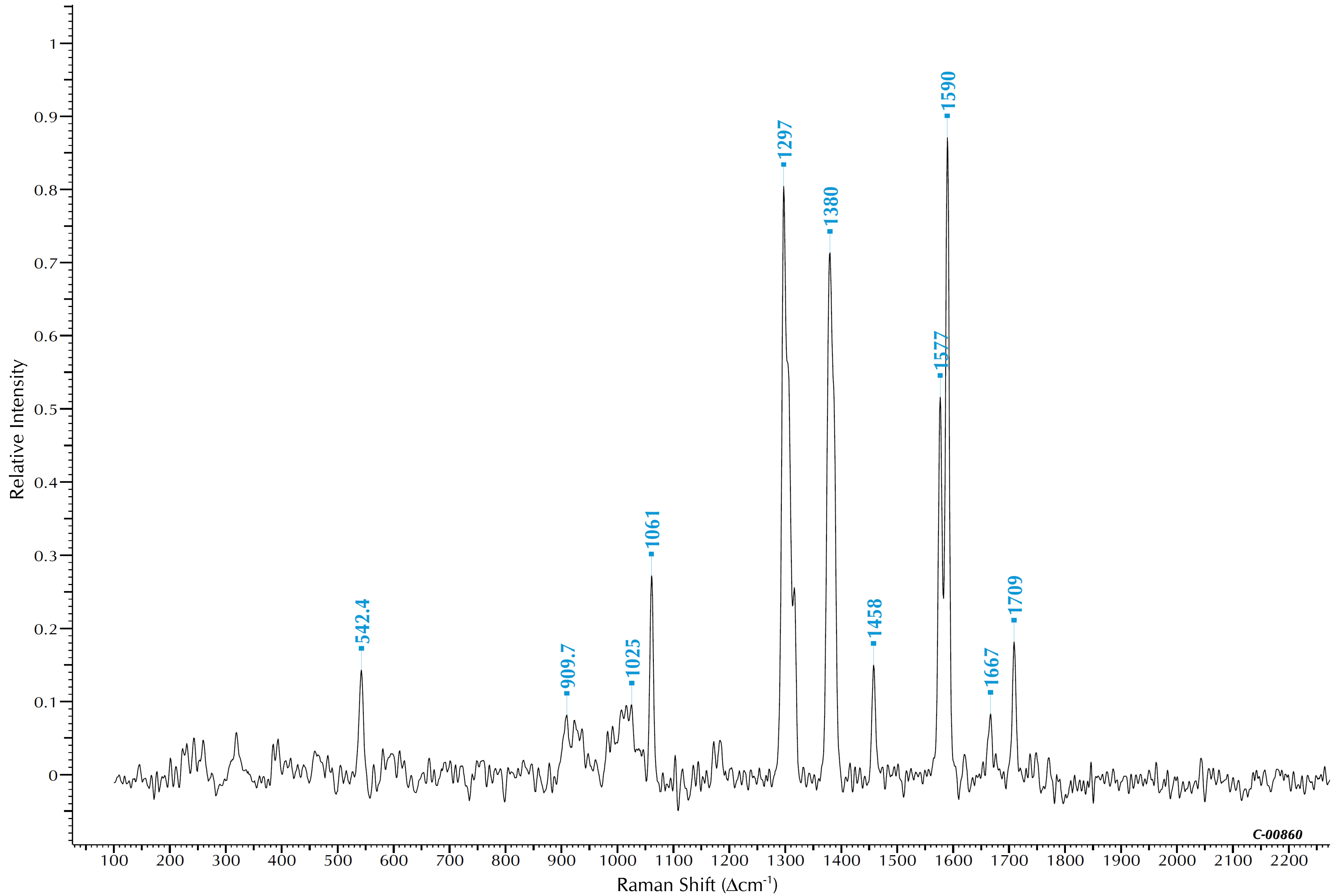
Chemical Category: Organic - Polycyclic - Quinacridone
Constitution Number: 73915

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 123



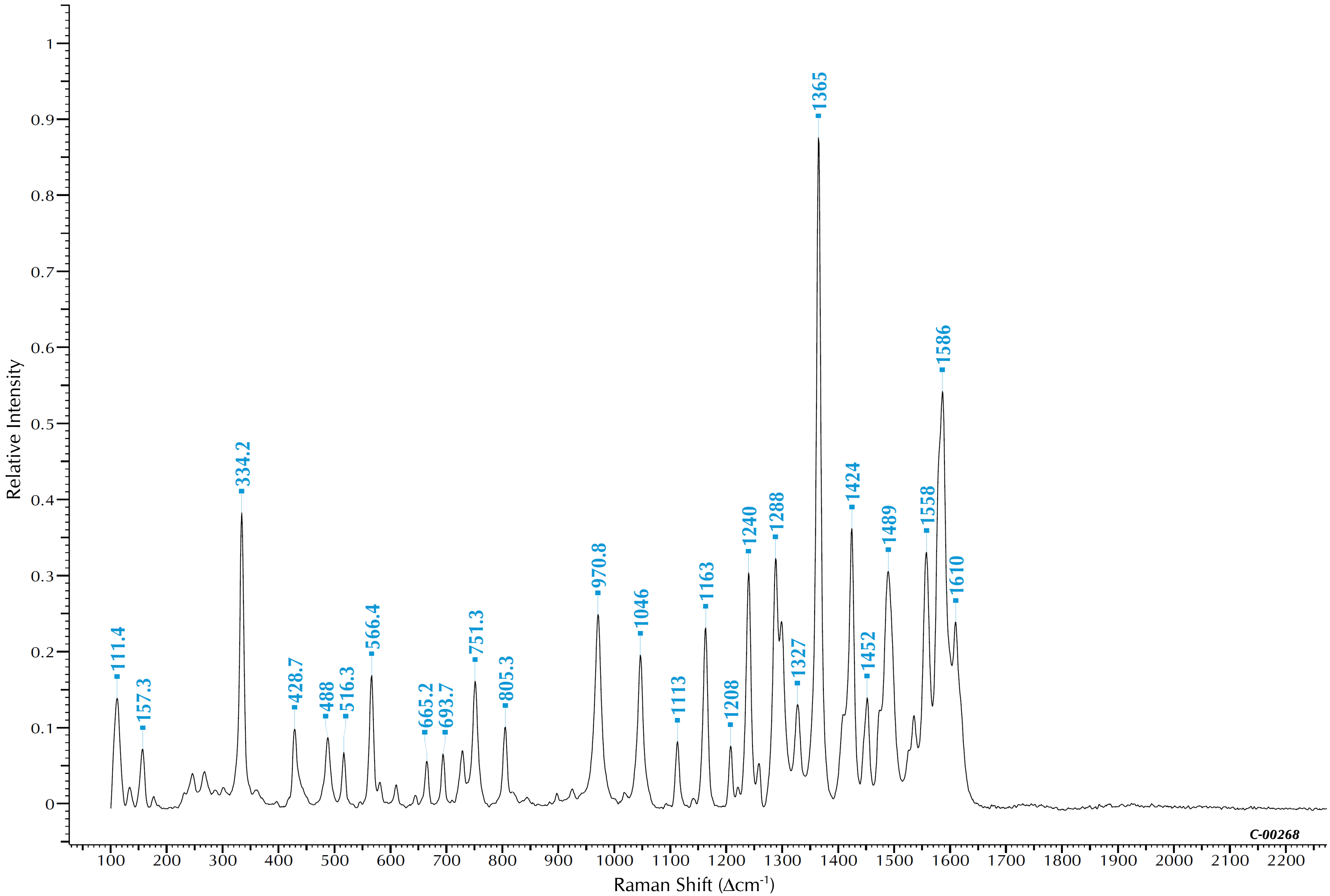
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71145

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Red 144



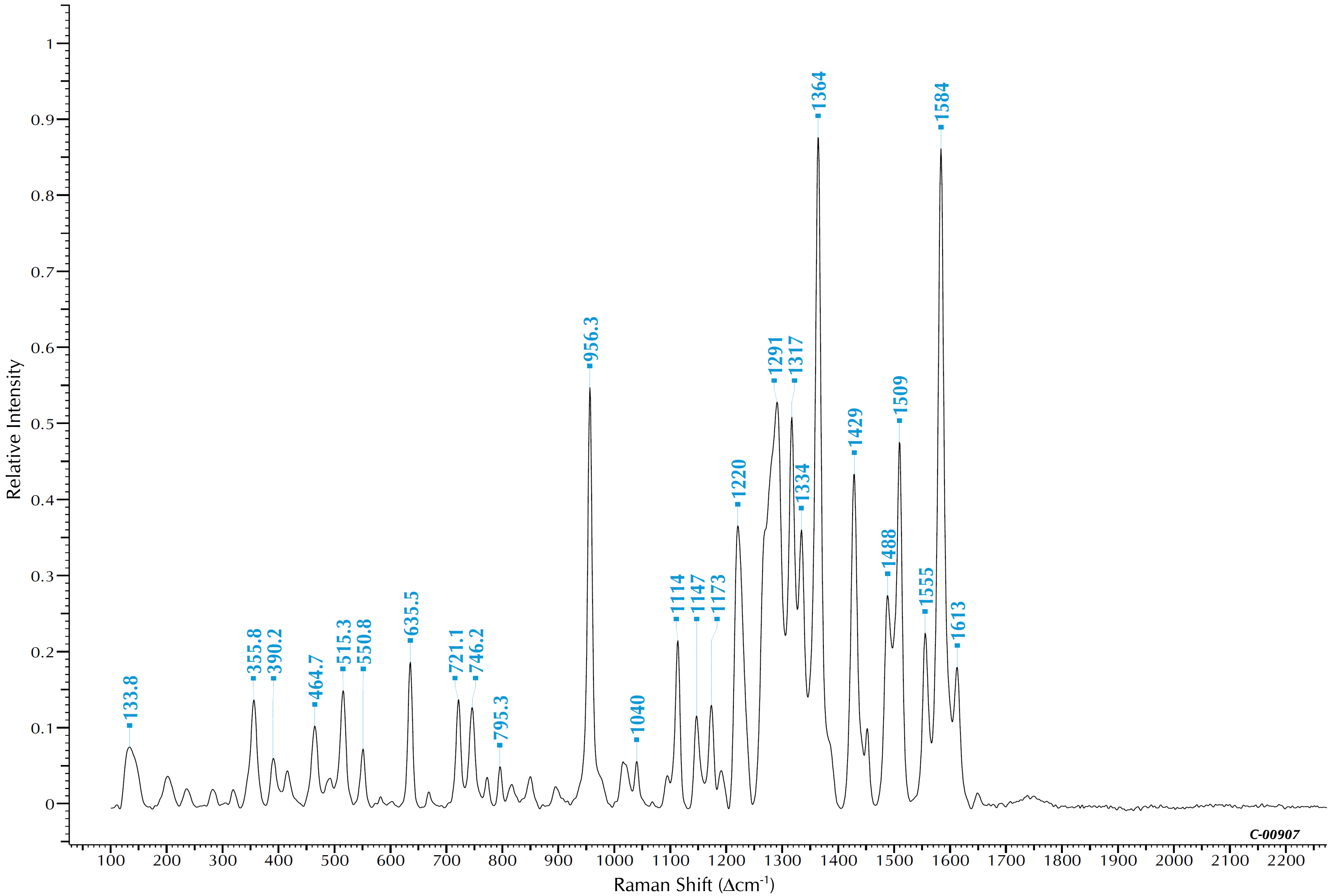
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20735

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 146



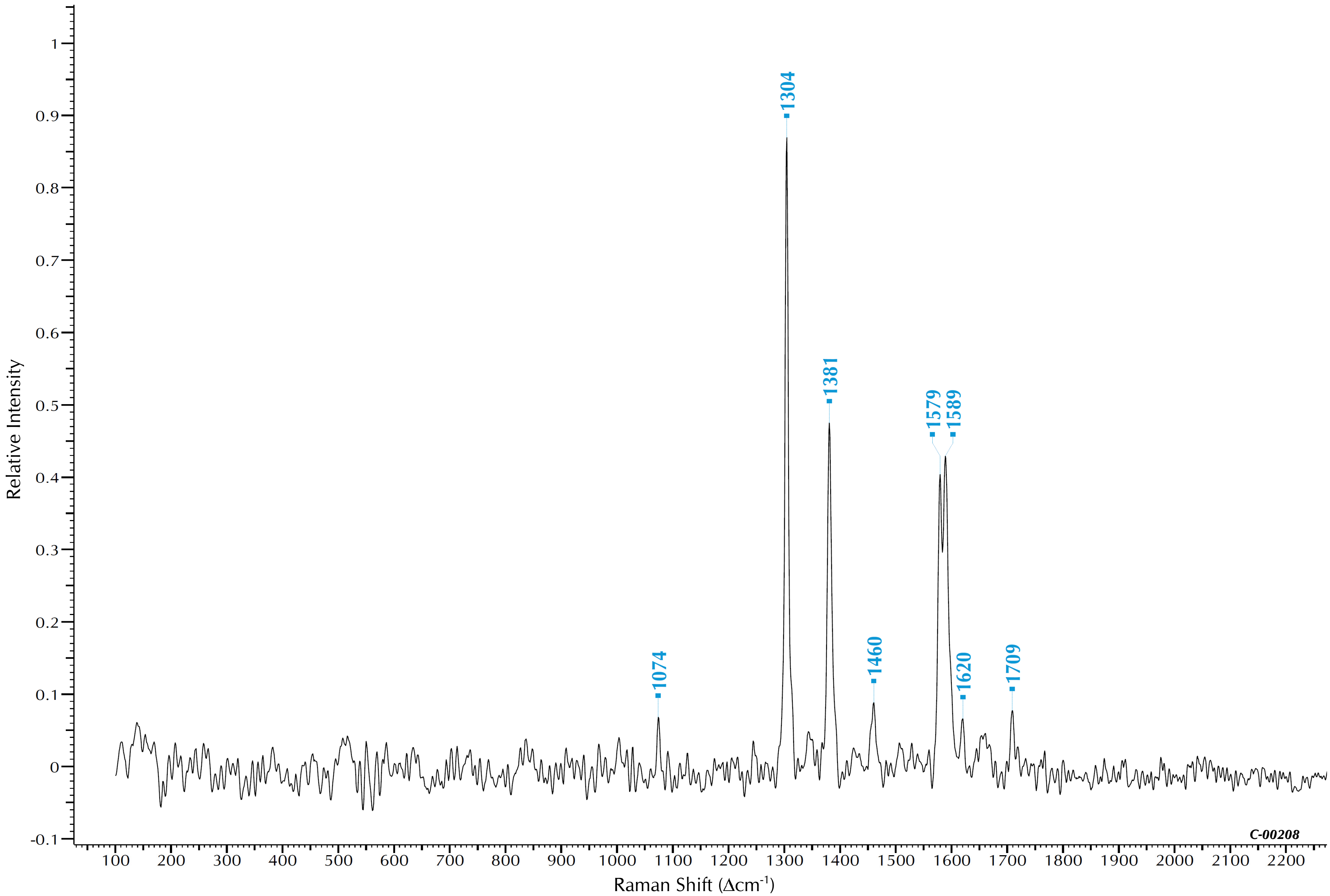
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12485

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 149



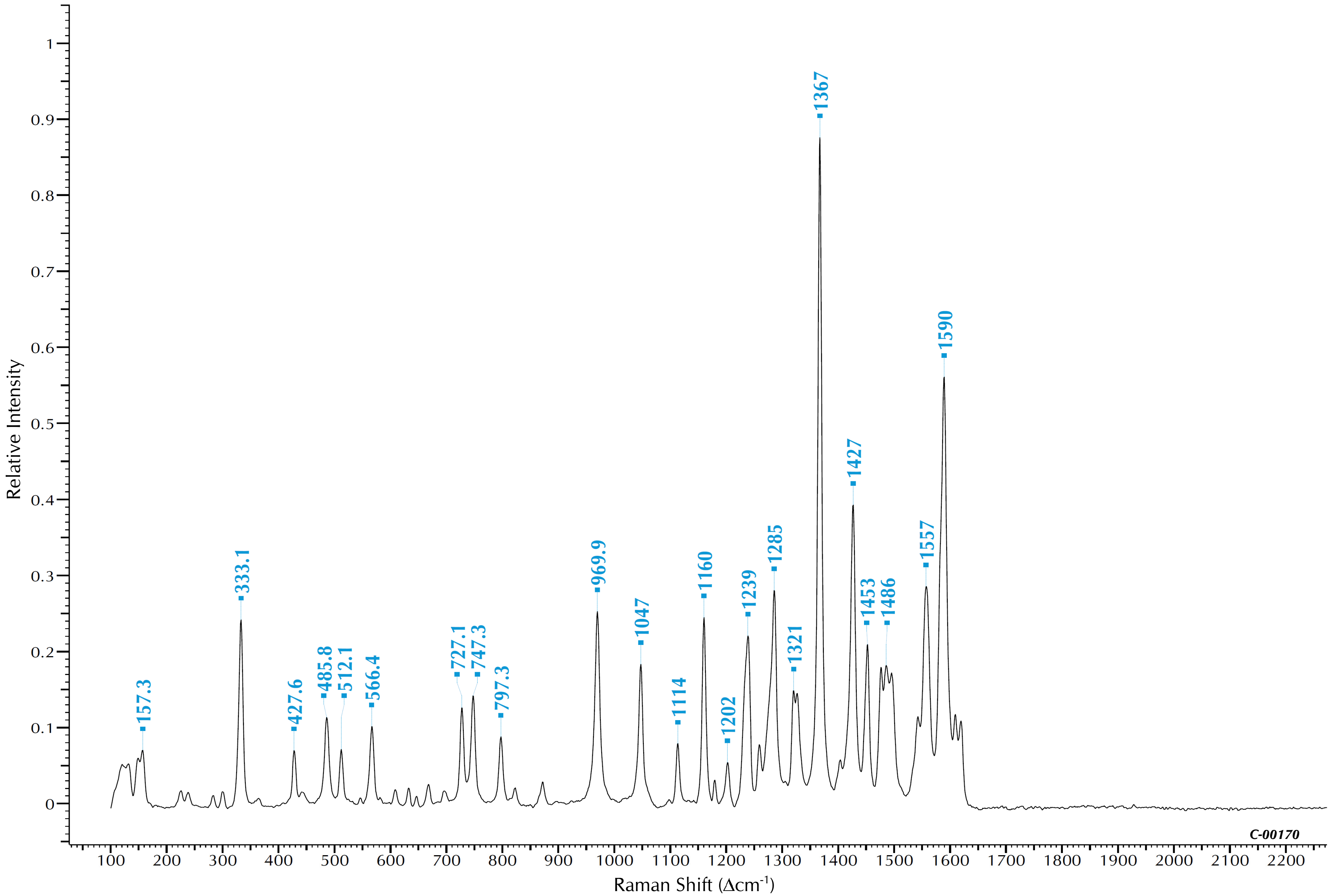
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71137

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Red 166



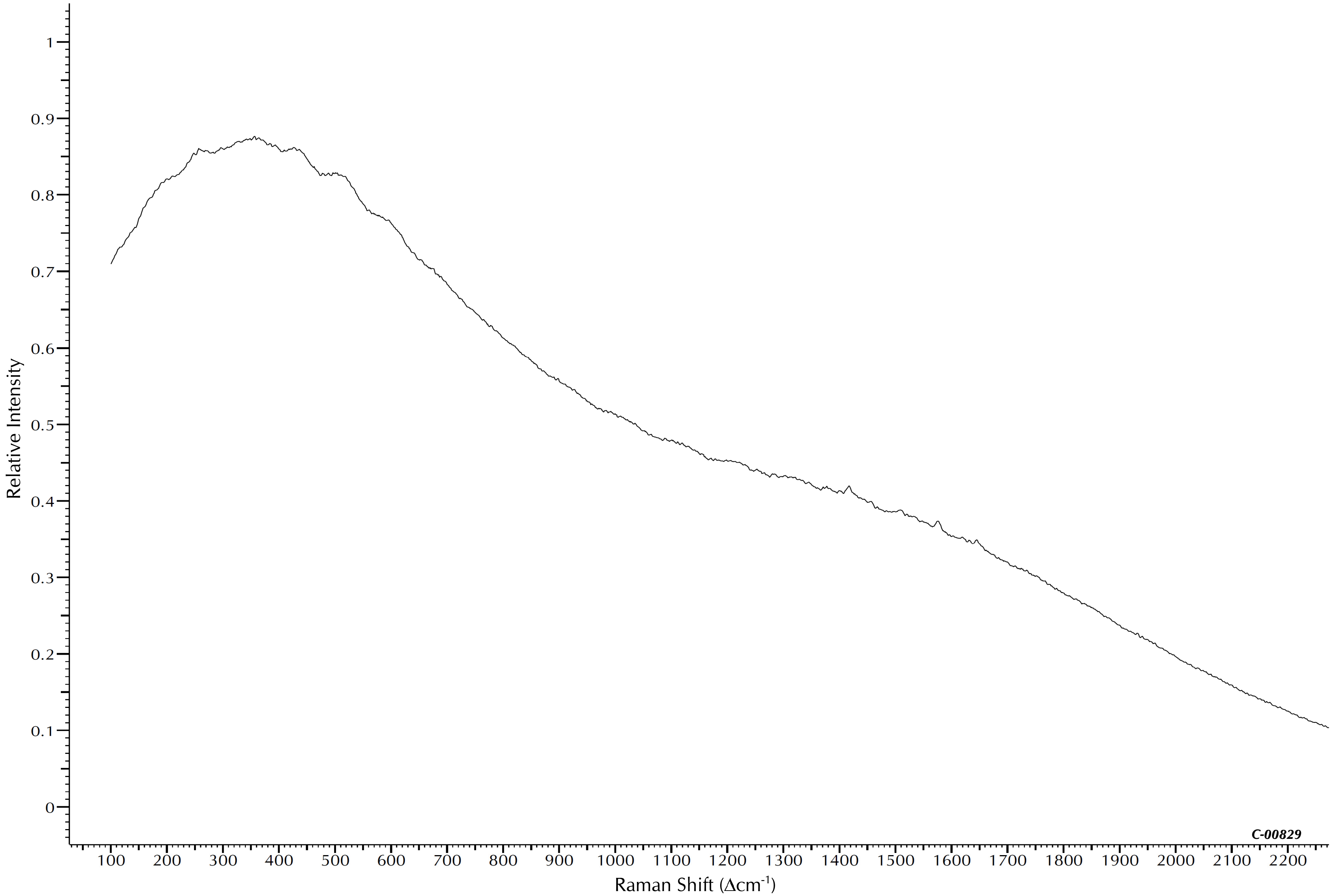
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20730

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 168



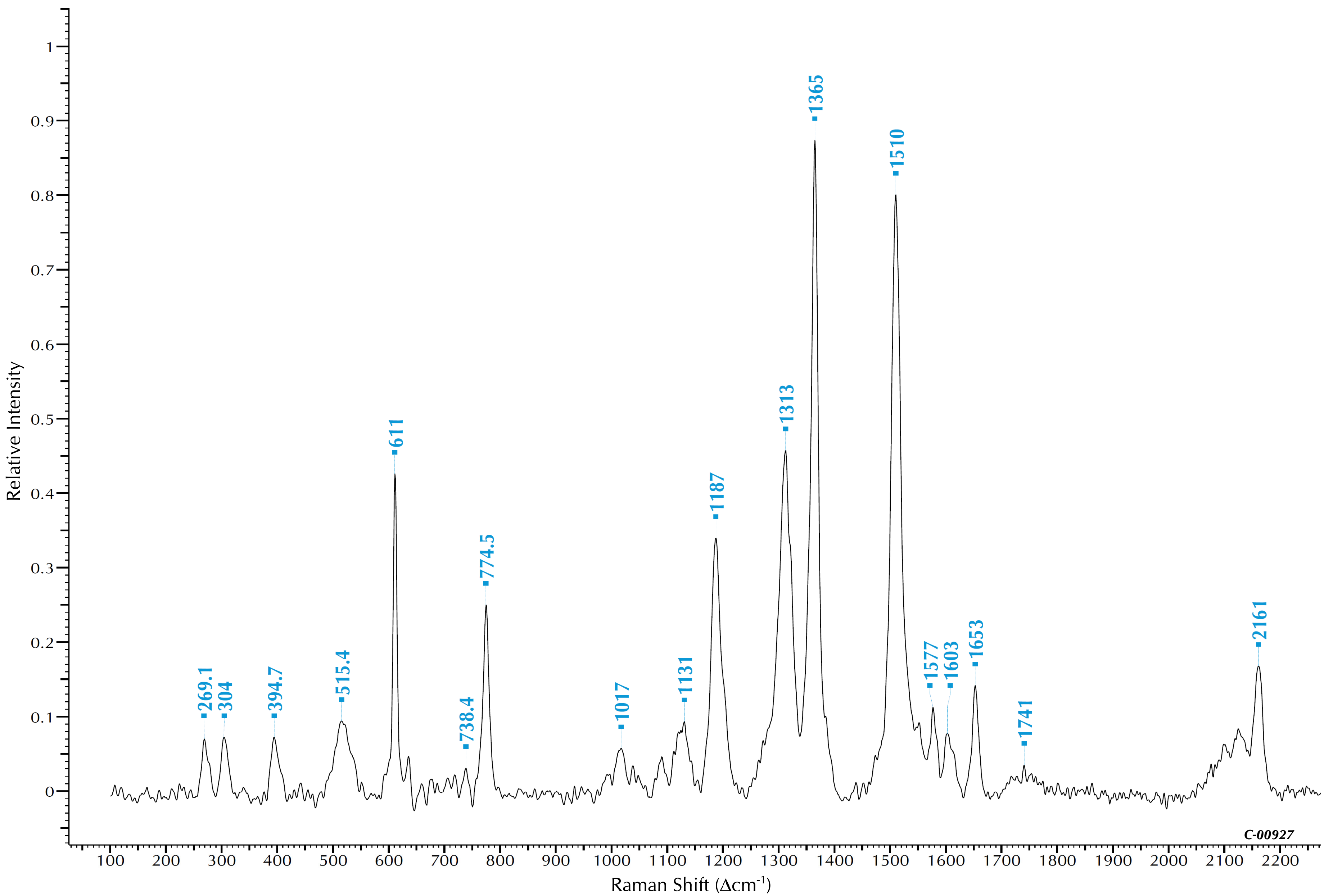
Chemical Category: Organic - Polycyclic - Polycarbocyclic Anthraquinone - Anthanthrone
Constitution Number: 59300

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Red 169



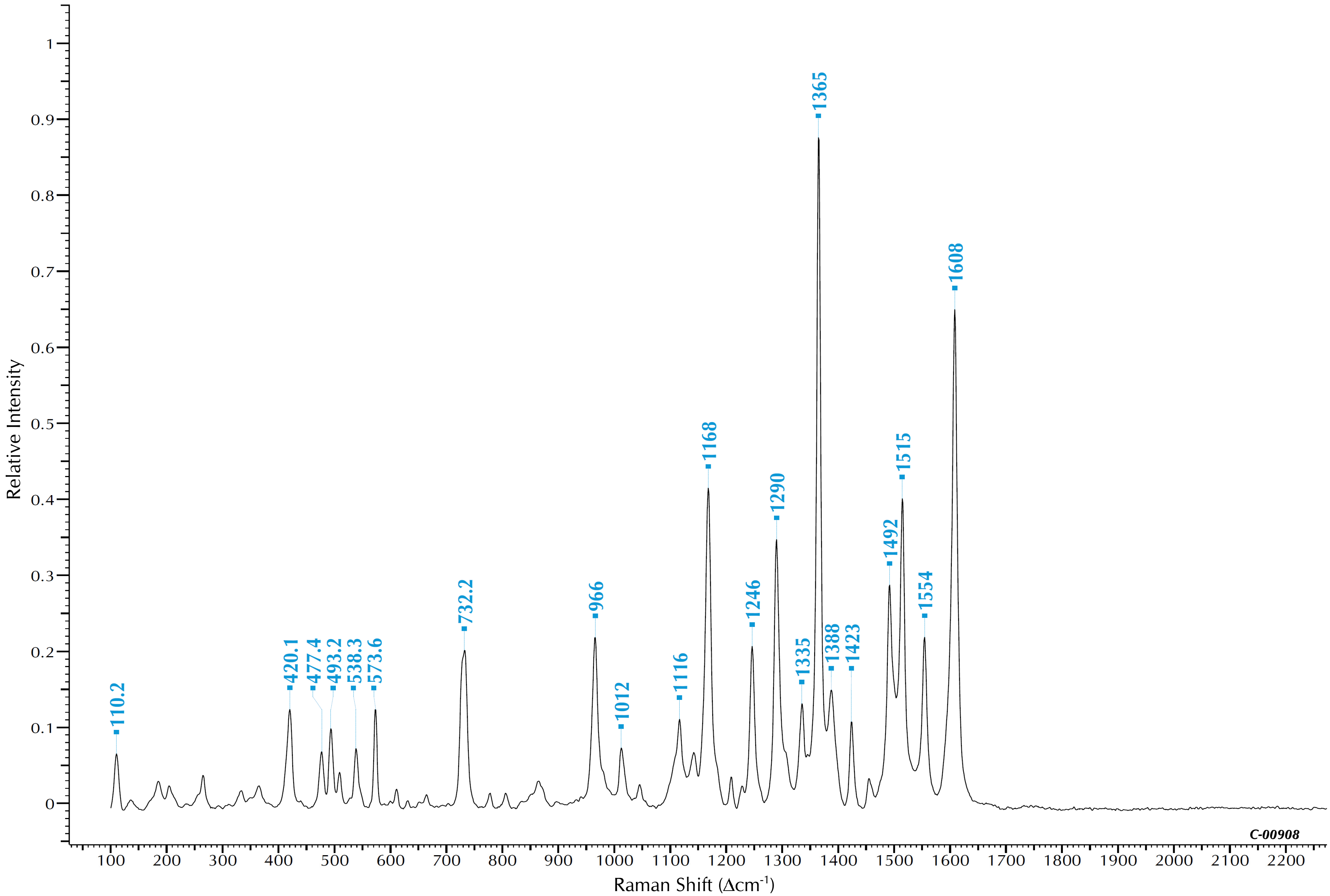
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45160:2

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 170



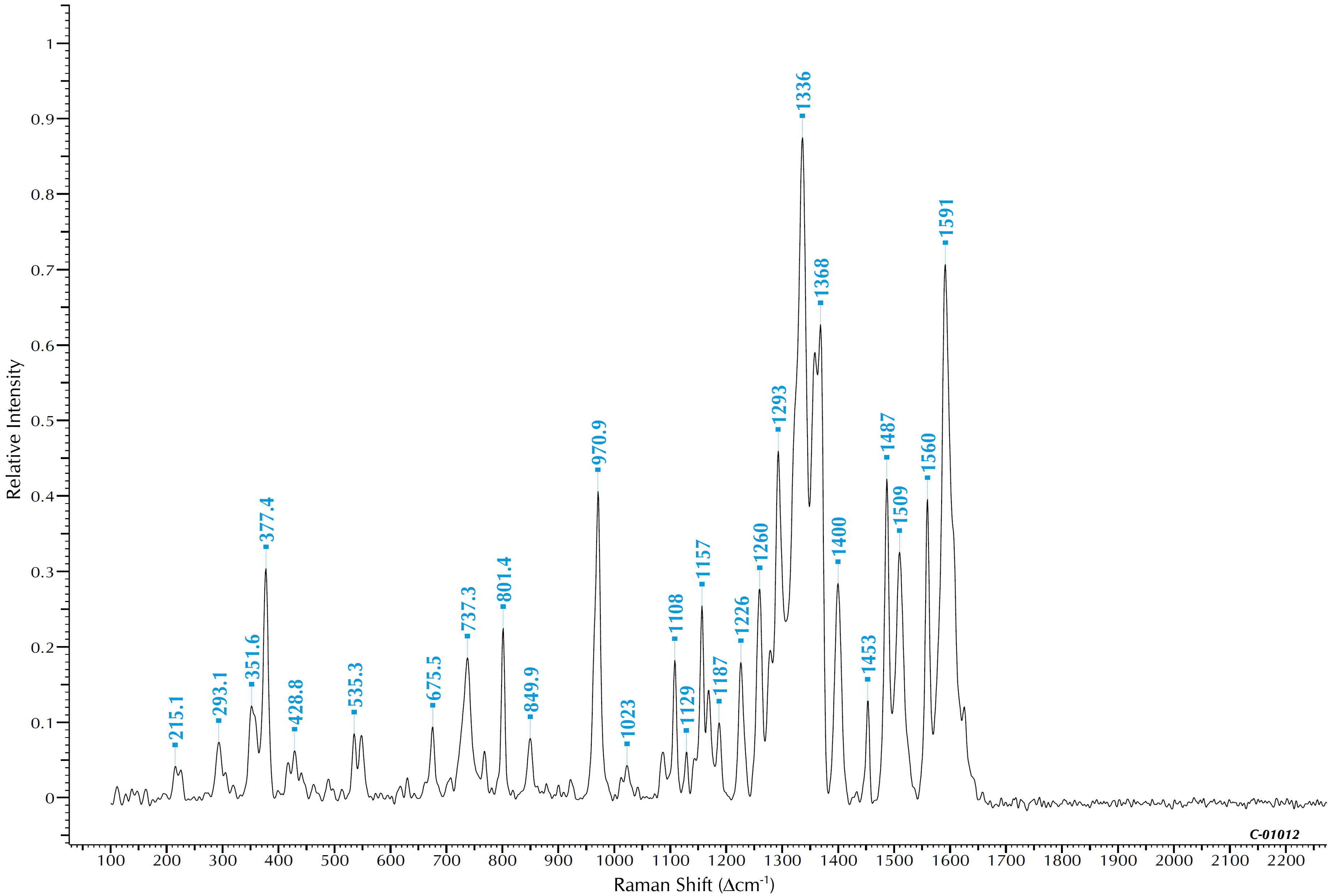
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12475

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 171



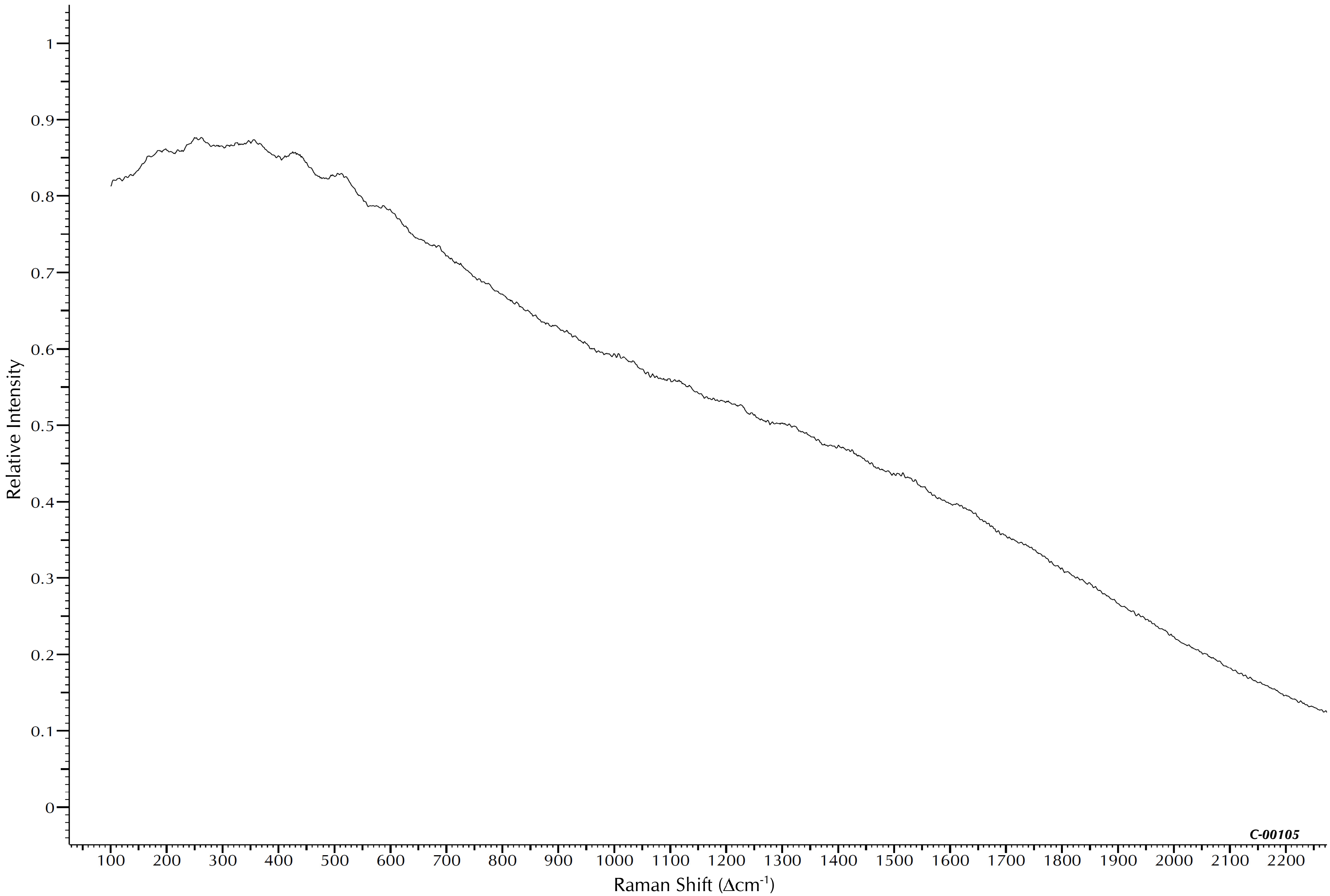
Chemical Category: Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)
Constitution Number: 12512

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 5

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 173



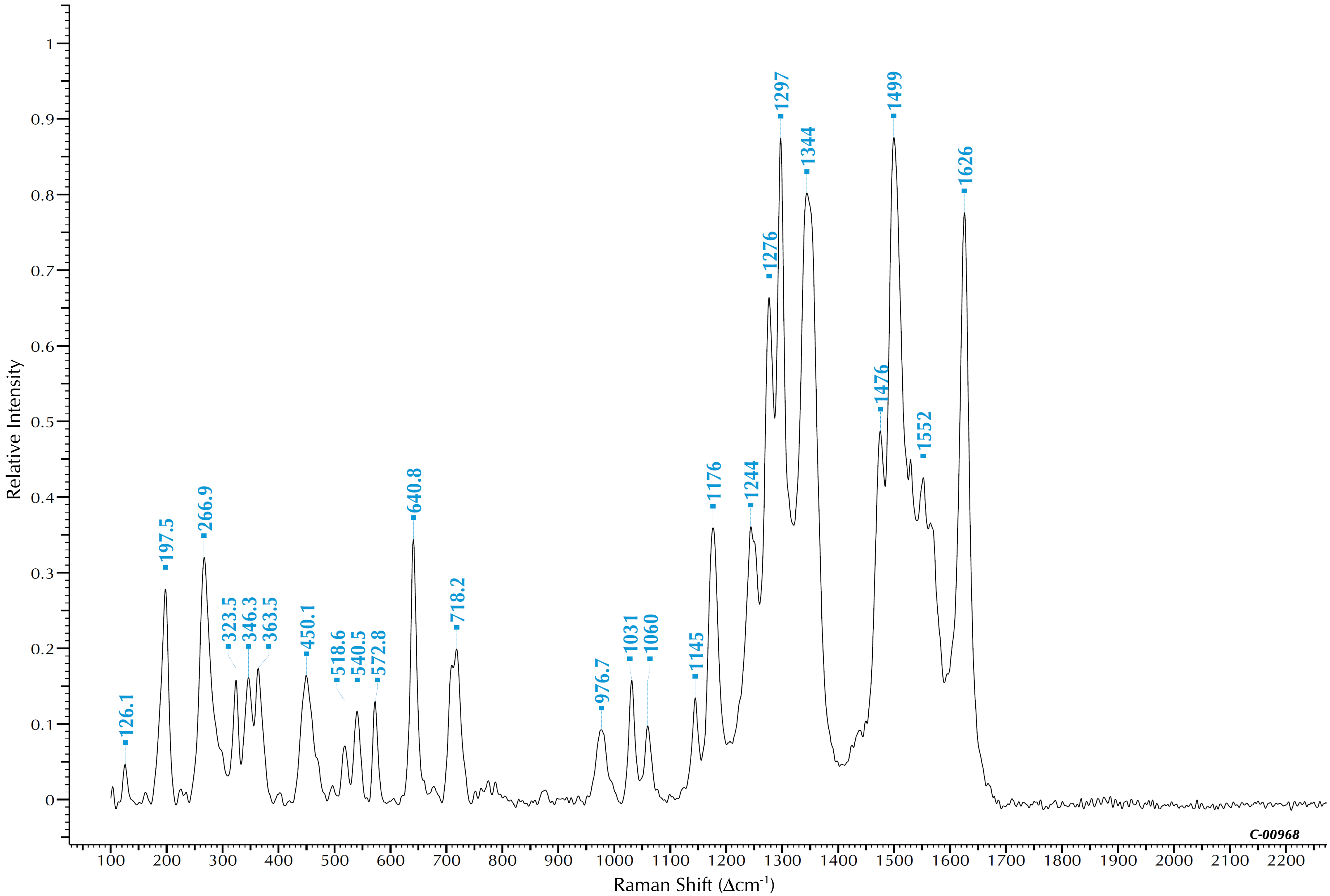
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45170:3

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Red 174



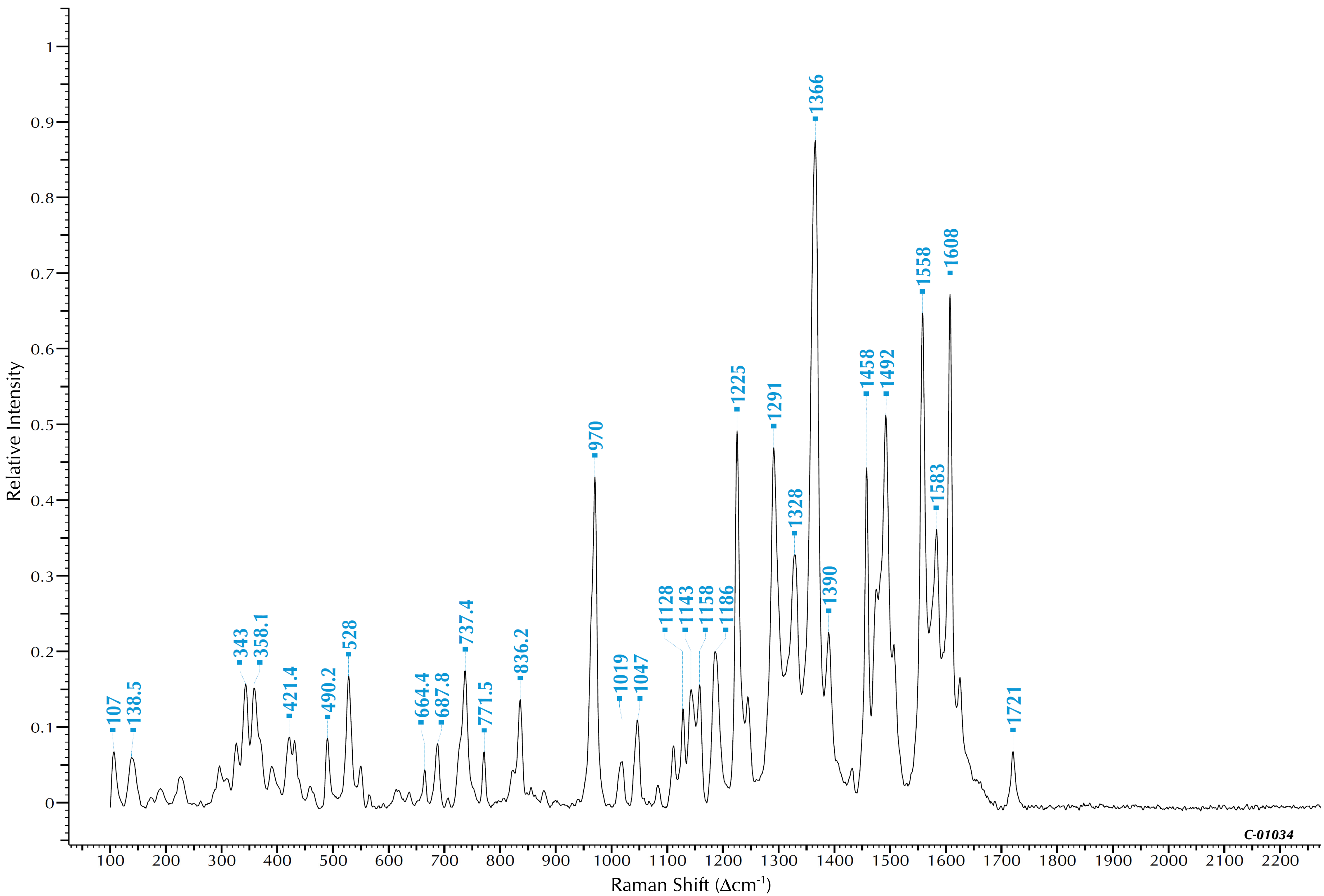
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45410:2

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 175



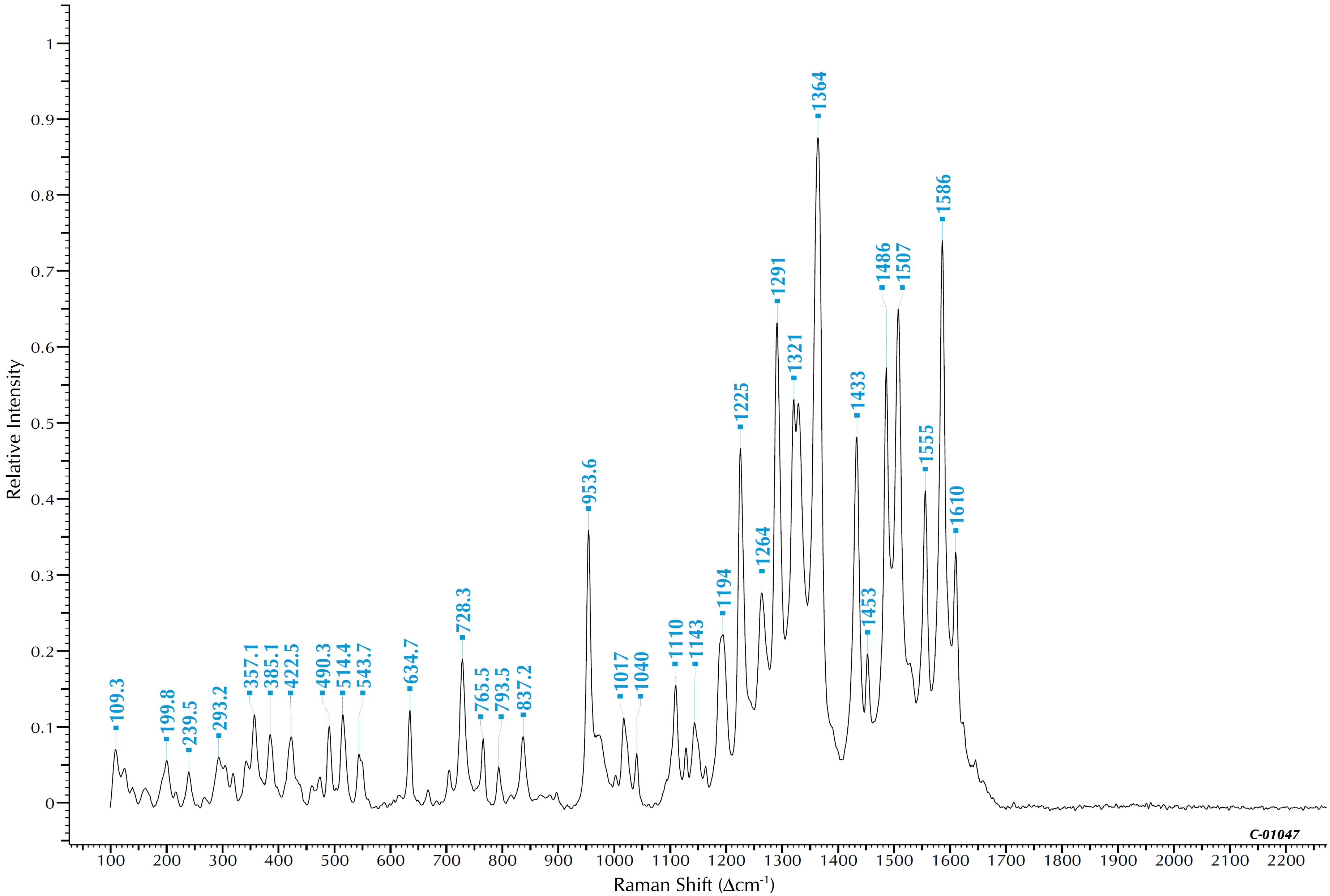
Chemical Category: Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)
Constitution Number: 12513

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Red 176



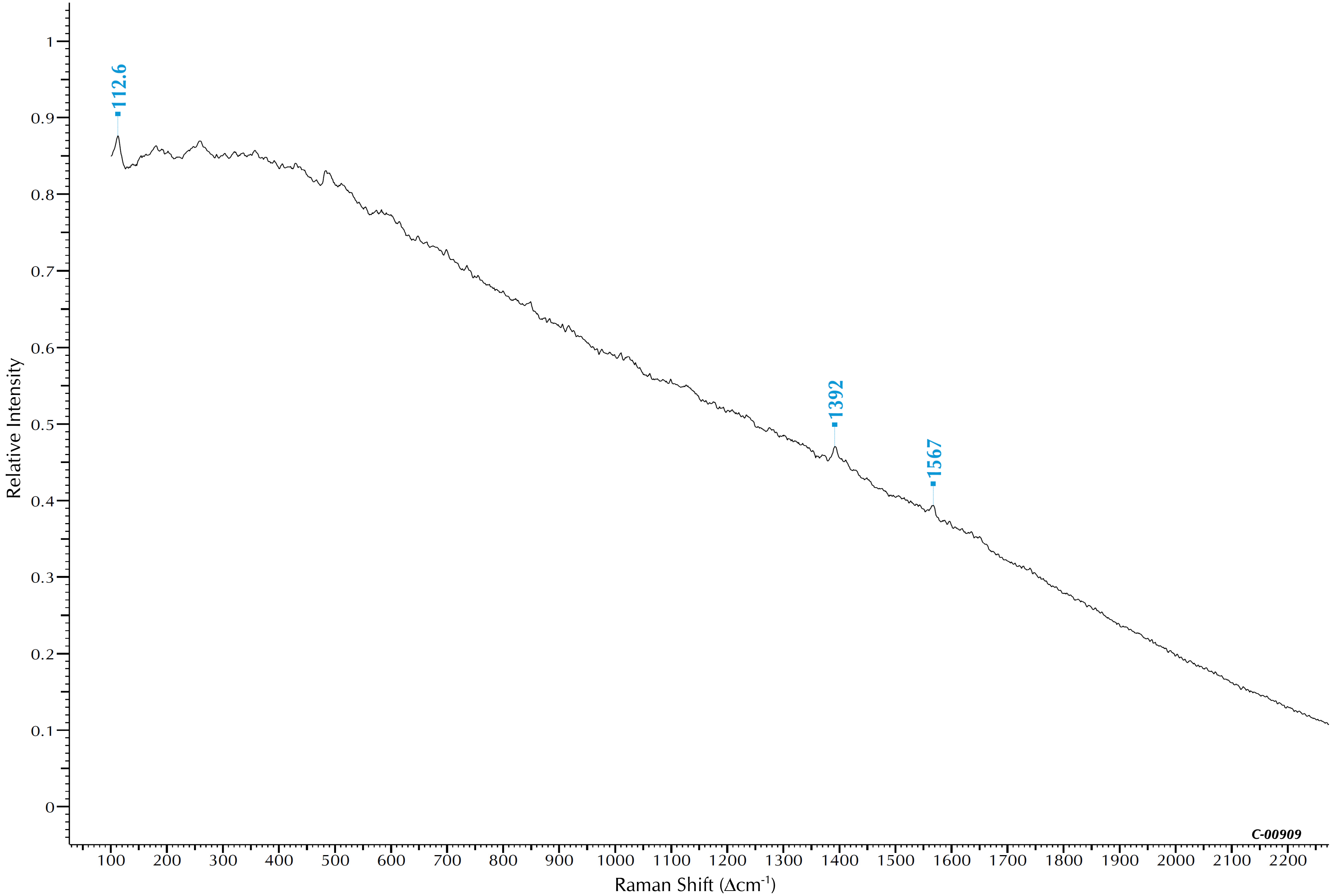
Chemical Category: Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)
Constitution Number: 12515

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 177



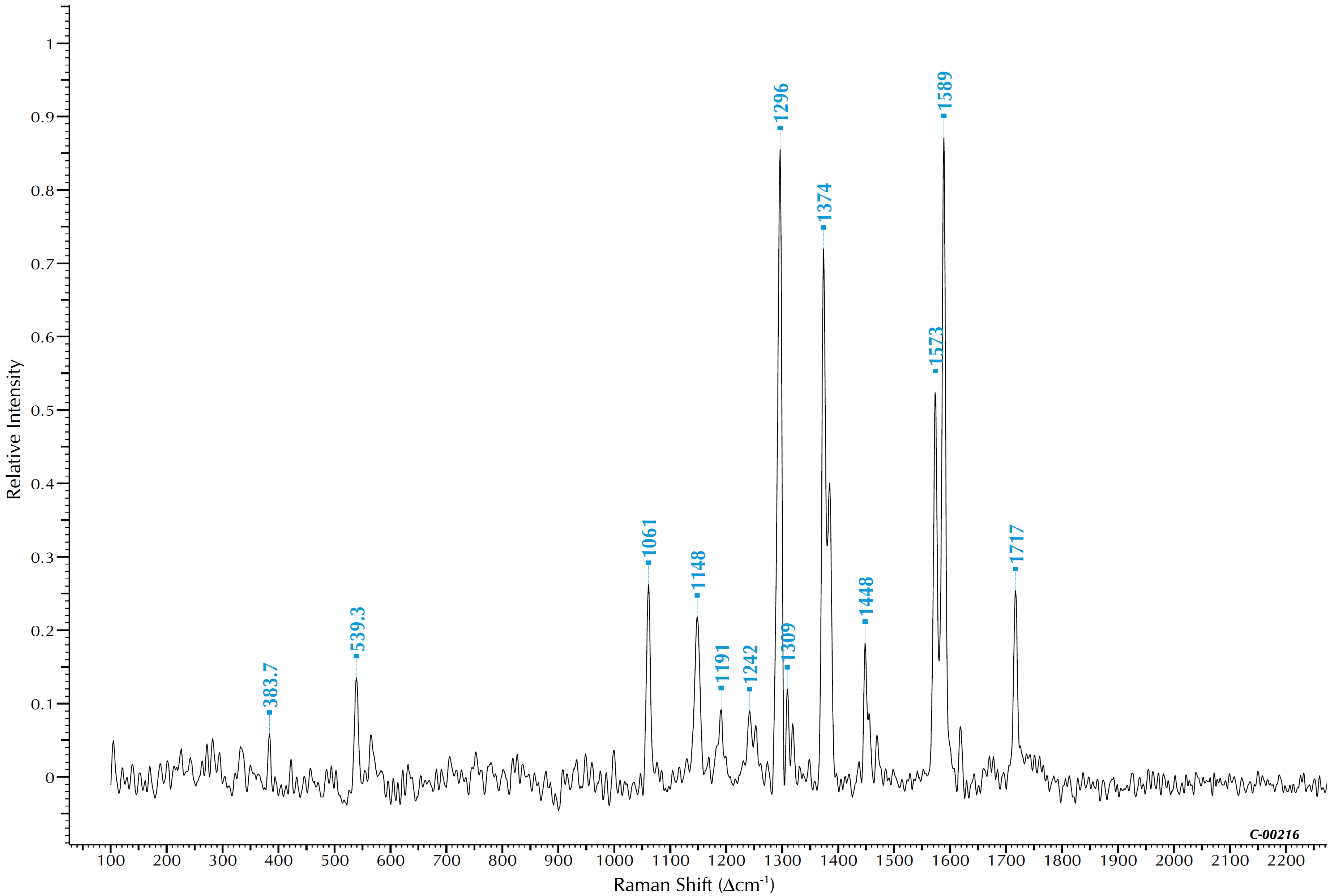
Chemical Category: Organic - Polycyclic - Aminoanthraquinone
Constitution Number: 65300

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Red 178



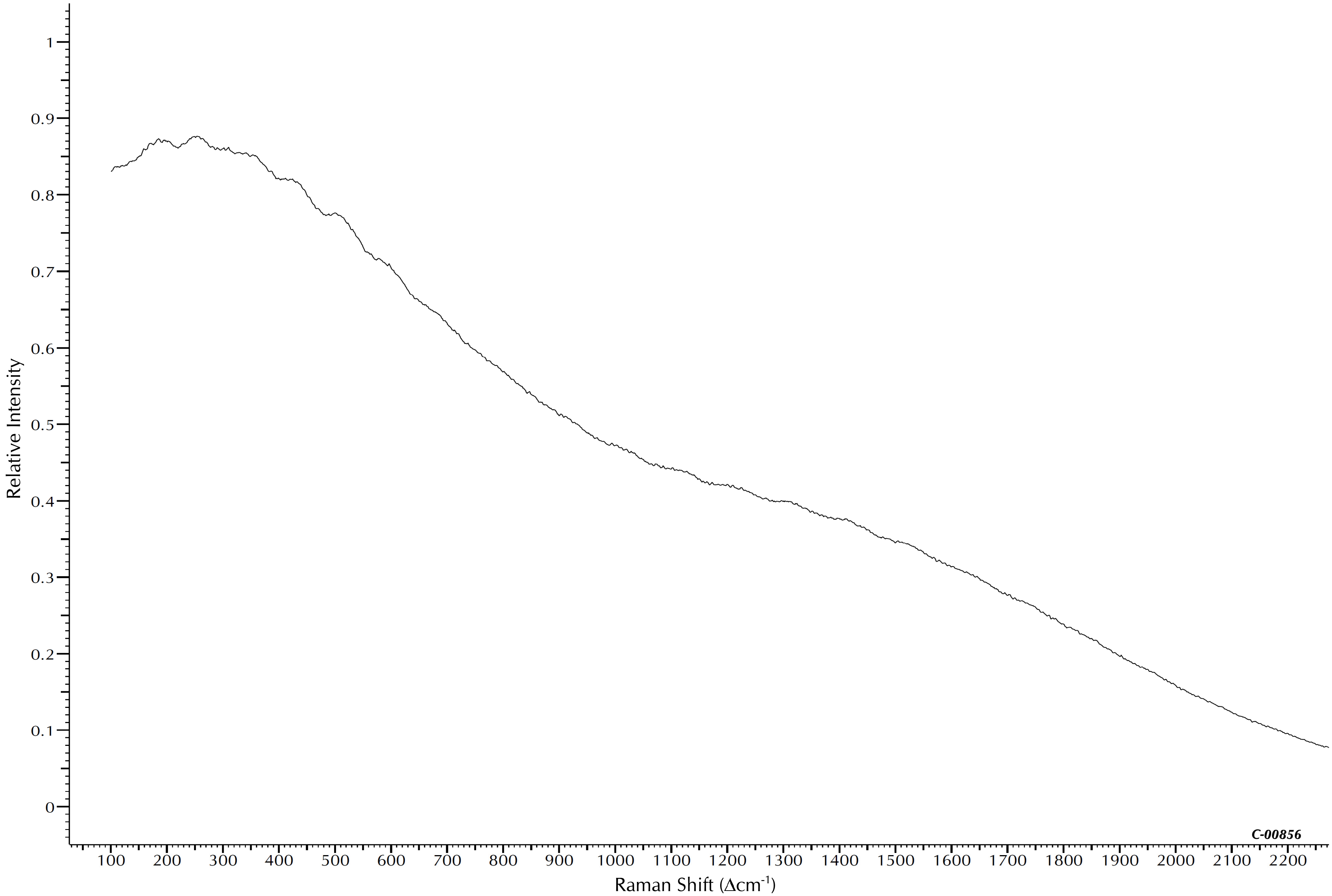
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71155

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Red 179



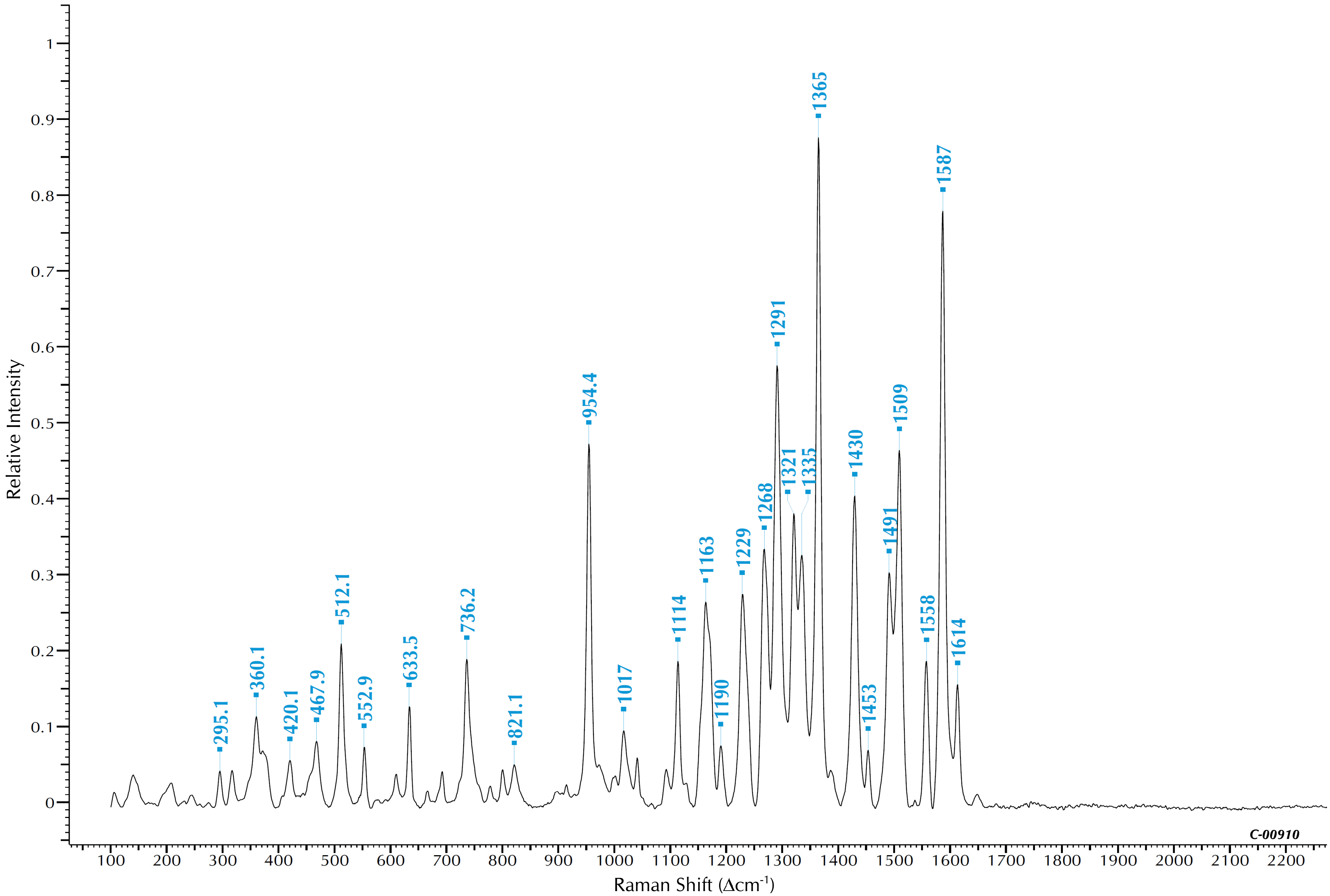
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71130

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.01
Quality Index 2

Microtrace LLC

C.I. Pigment Red 184



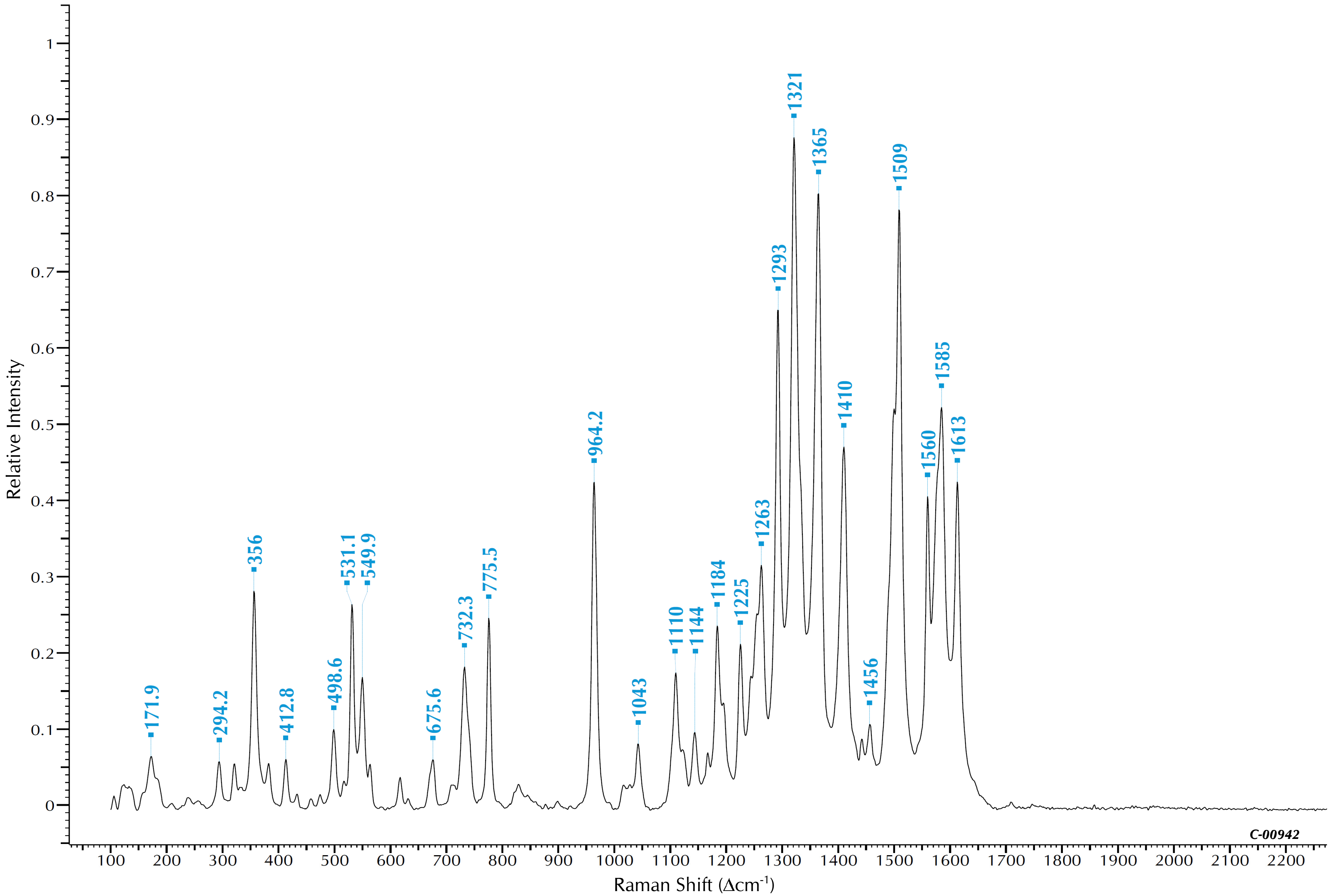
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12487 12433; 12485

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 2

Microtrace LLC

C.I. Pigment Red 185



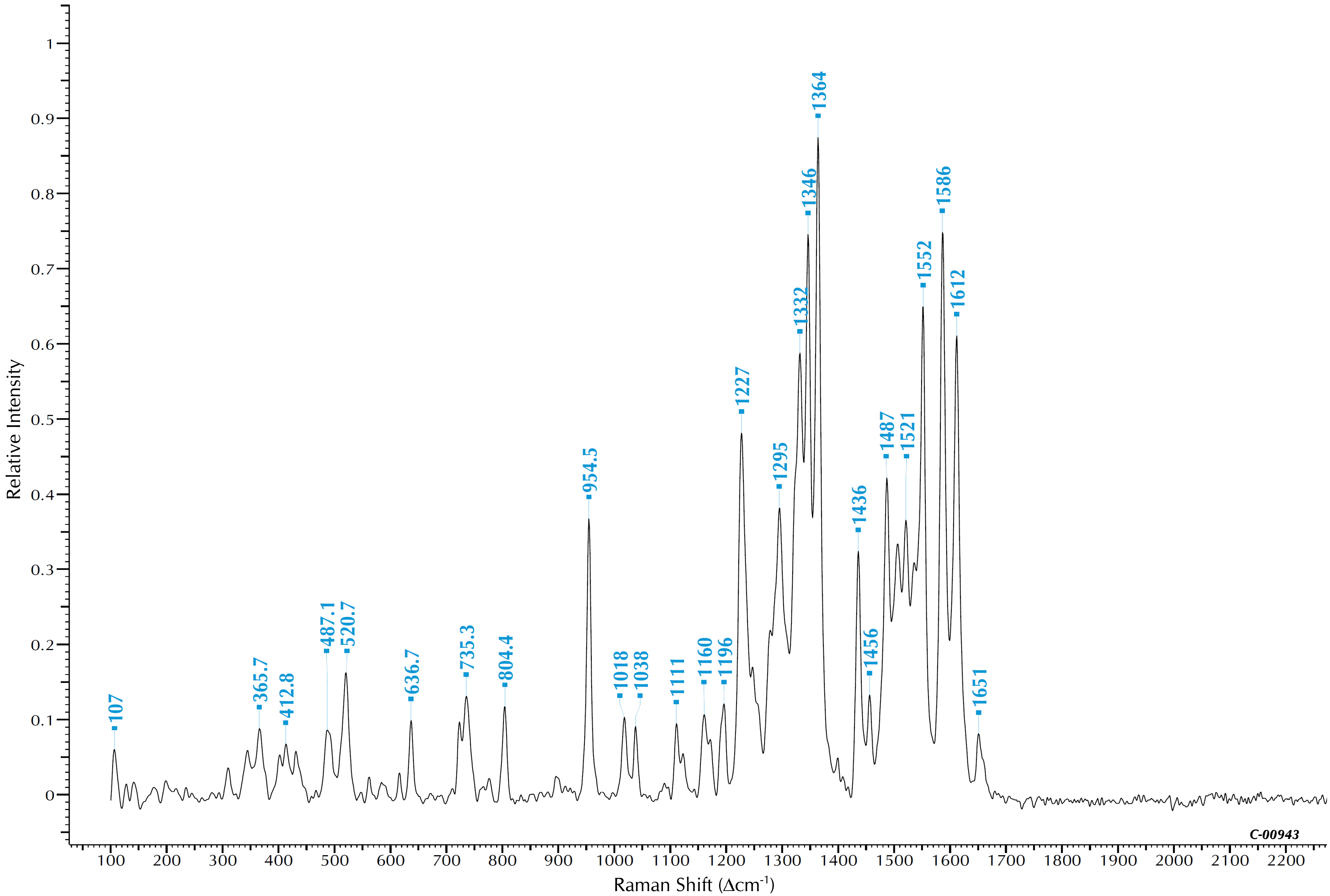
Chemical Category: Organic - Azo - Benzimidazolone - Group 2 (red/brown/violet)
Constitution Number: 12516

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 187



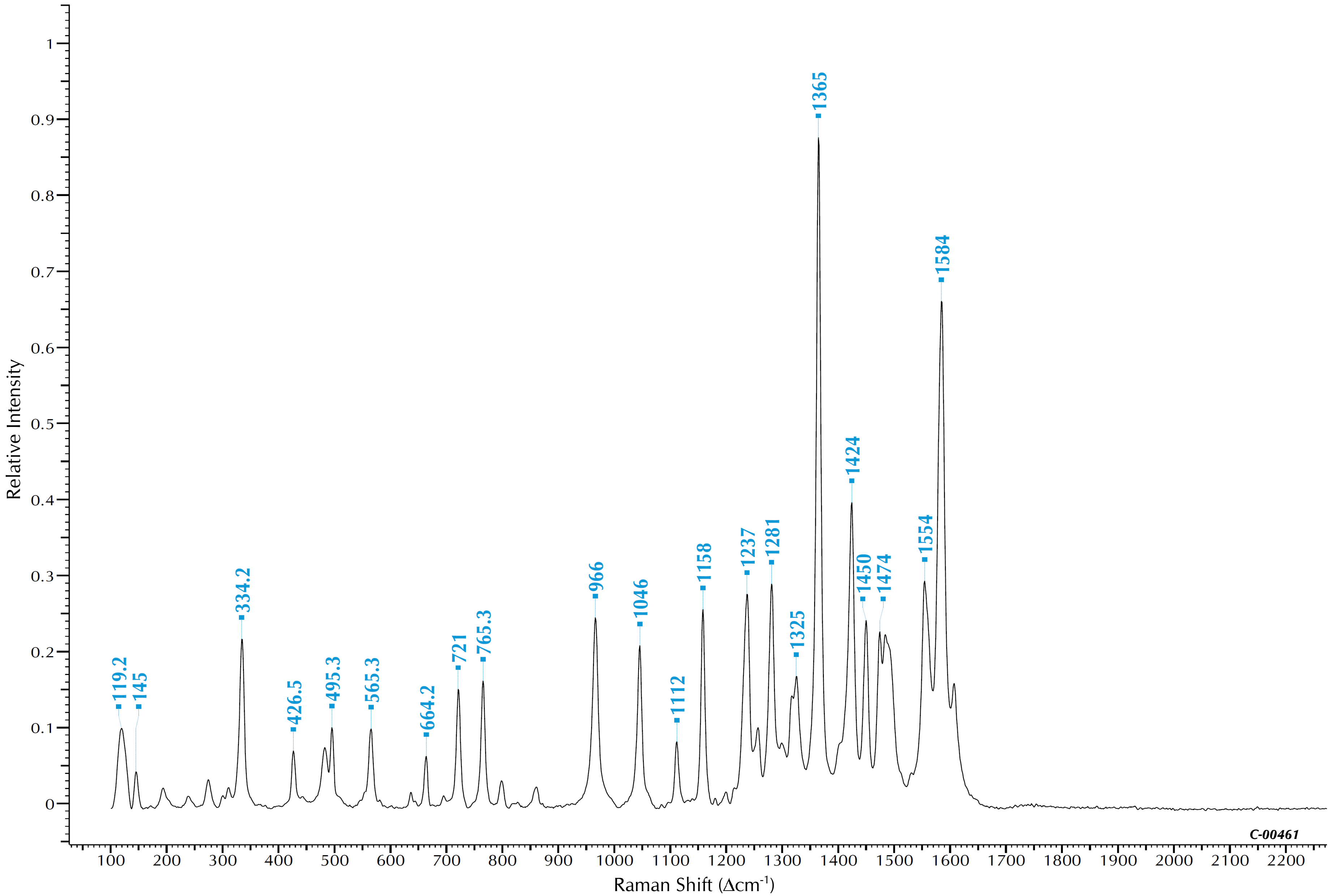
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12486

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 188



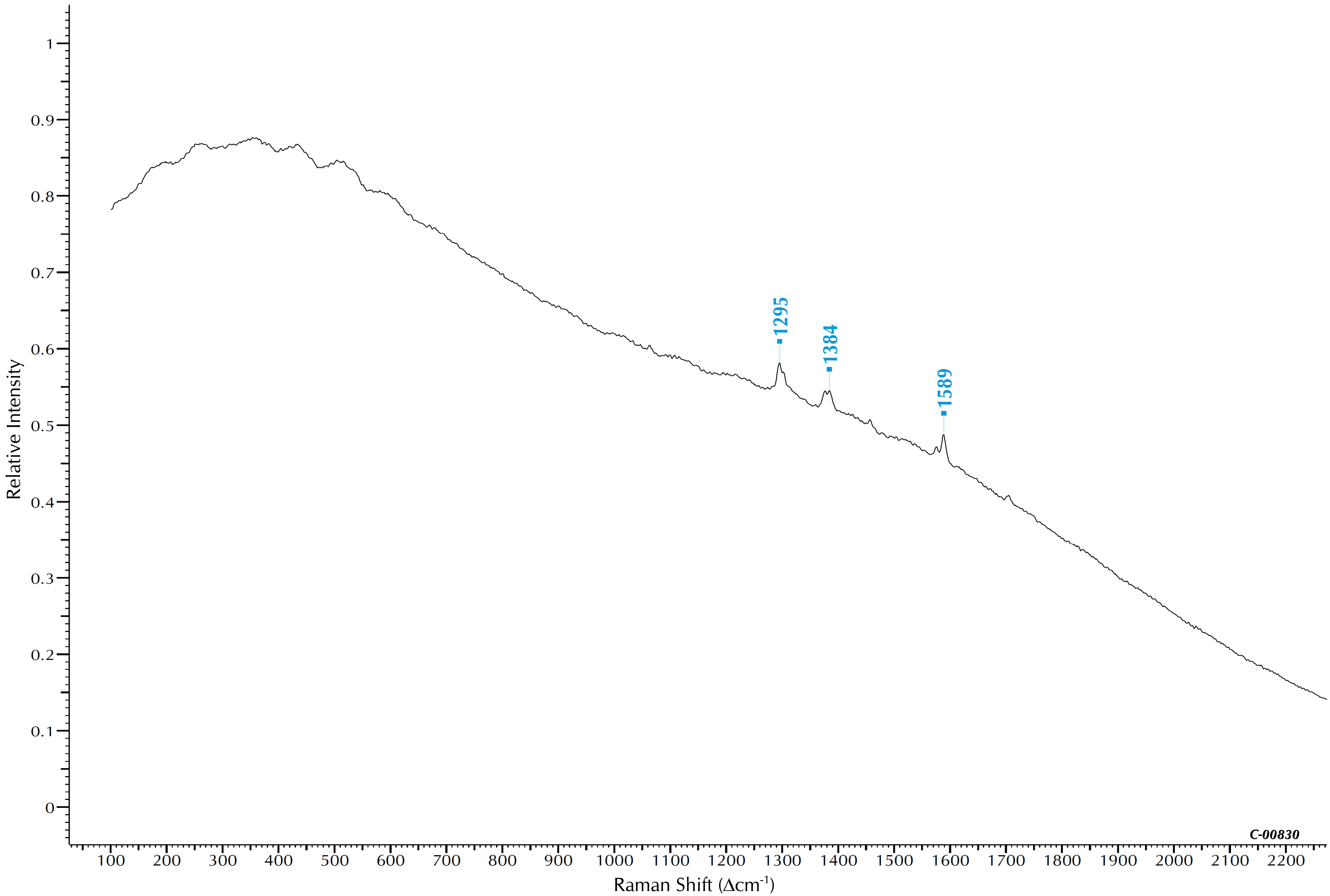
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12467

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 4

Microtrace LLC

C.I. Pigment Red 190



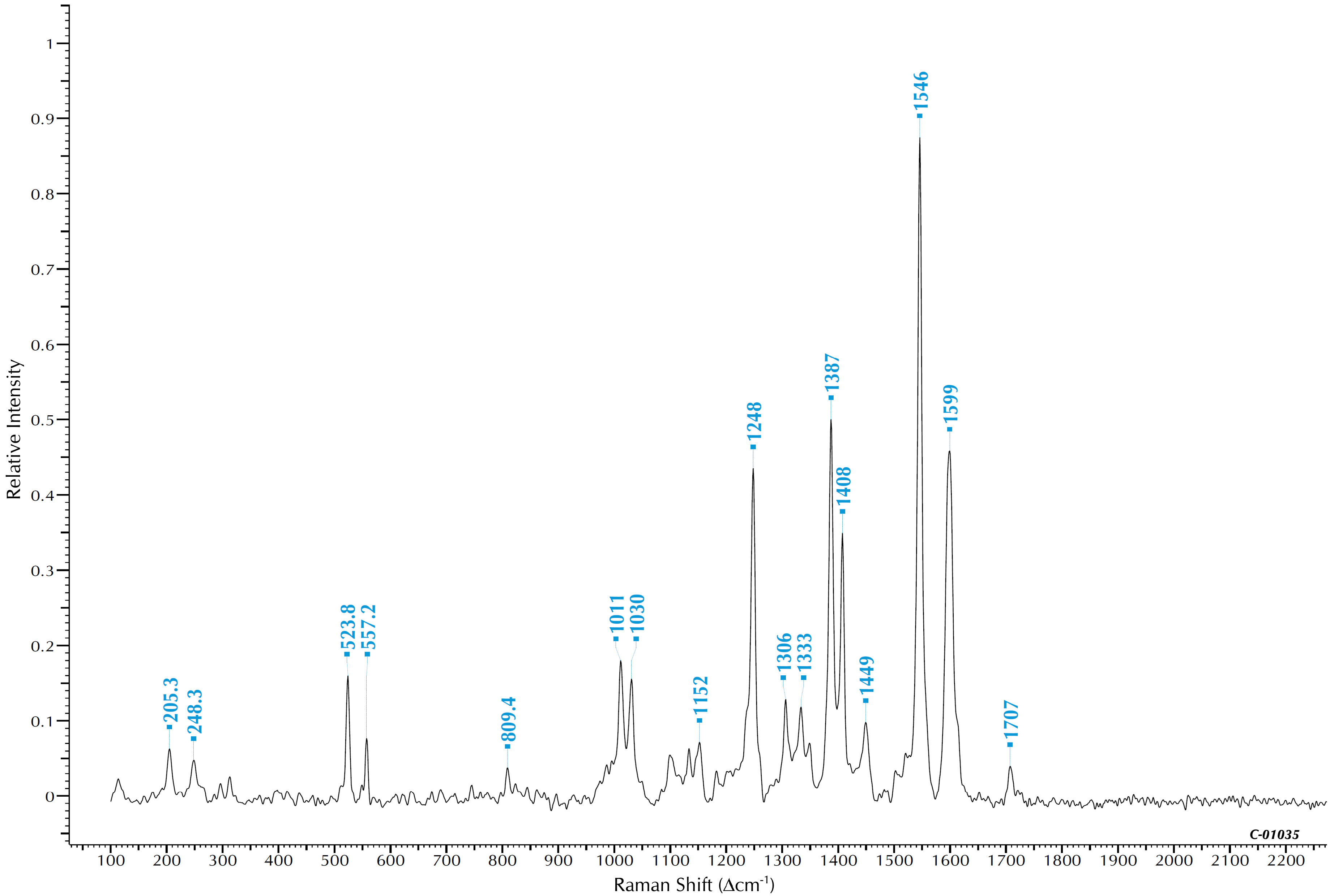
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71140

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Red 194



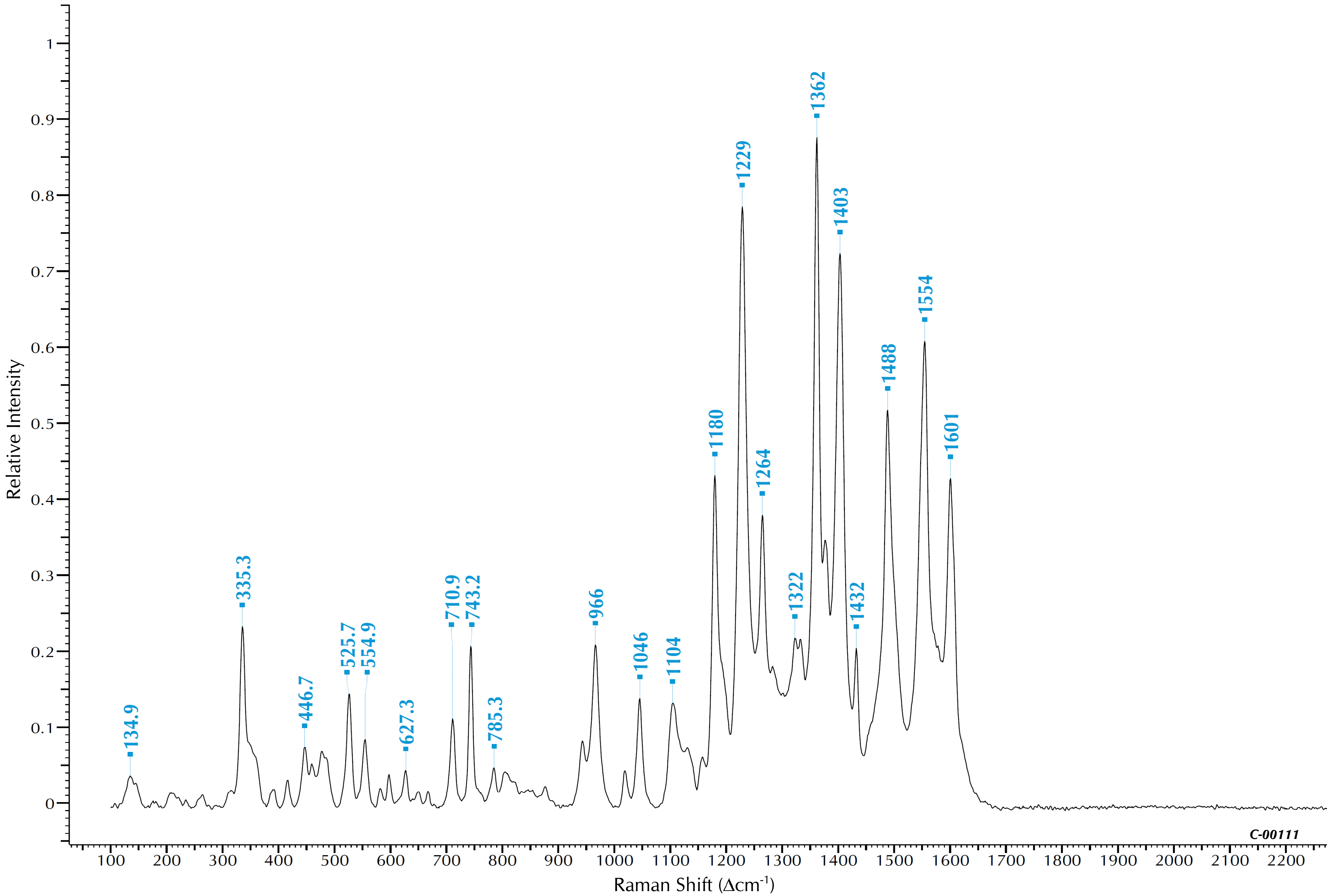
Chemical Category: Organic - Polycyclic - Perinone
Constitution Number: 71100

Bleaching Time (s): 60
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 200



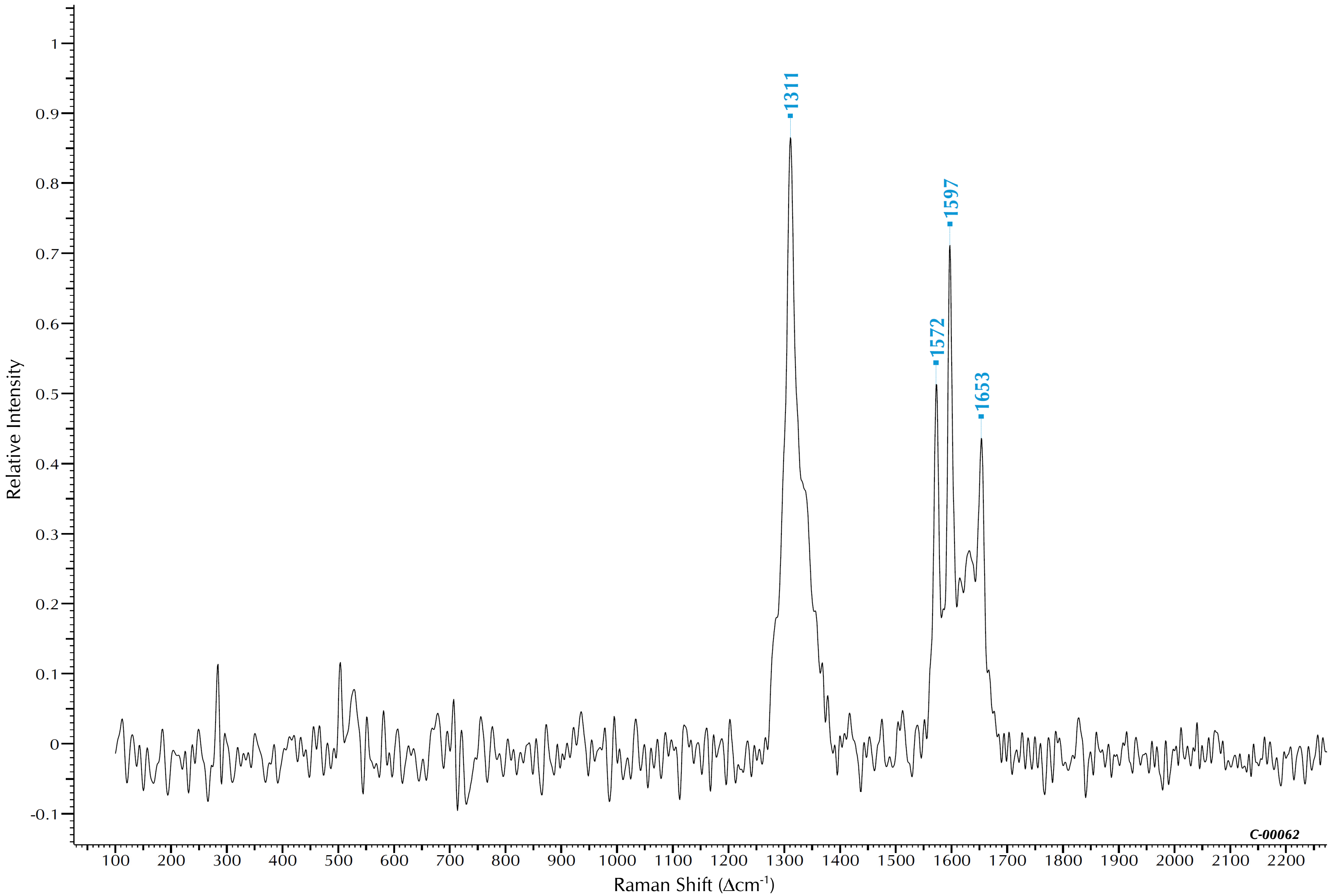
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Beta Oxynaphthoic Acid Lake
Constitution Number: 15867

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Red 202



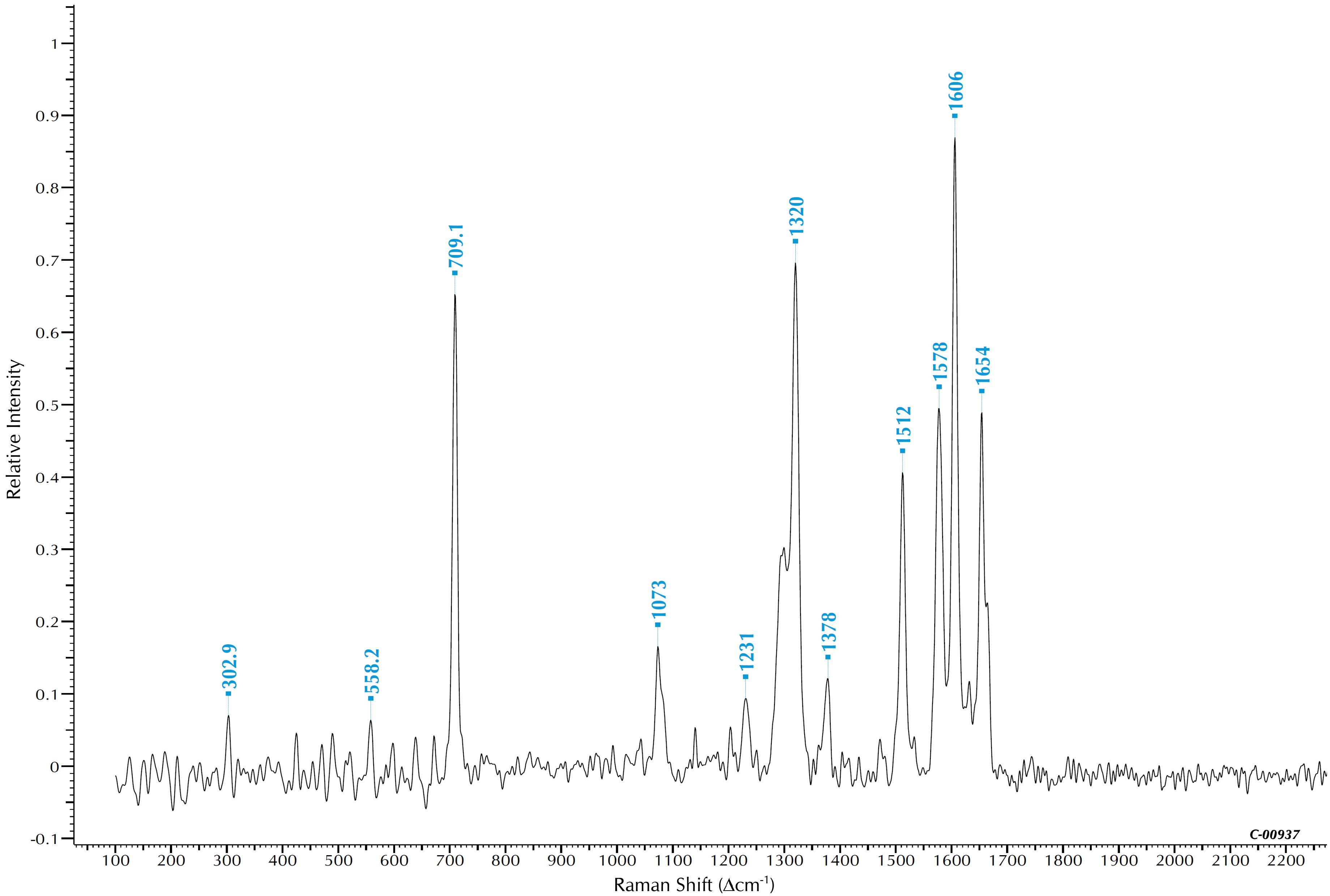
Chemical Category: Organic - Polycyclic - Quinacridone
Constitution Number: 73907

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Red 209



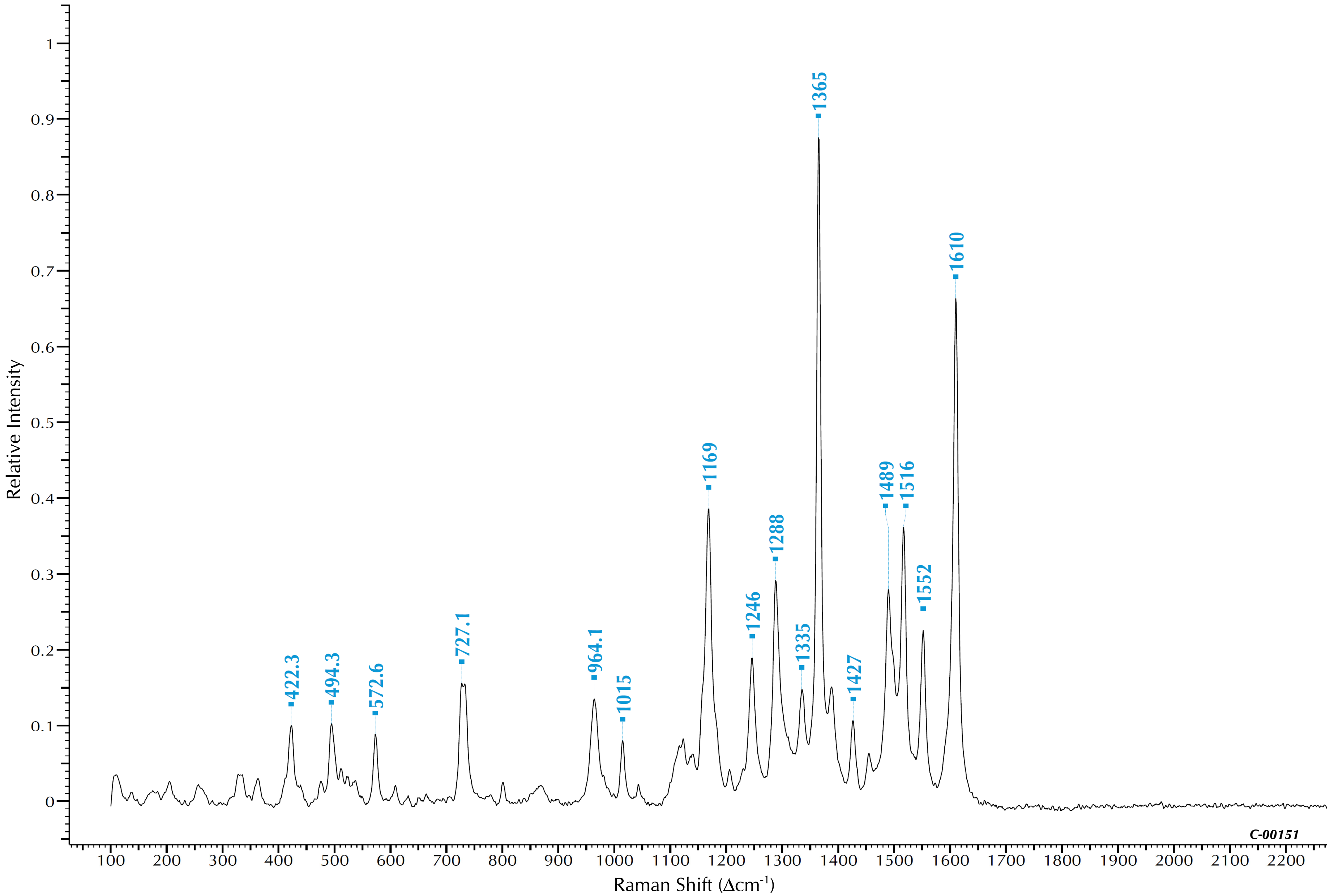
Chemical Category: Organic - Polycyclic - Quinacridone
Constitution Number: 73905

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 210



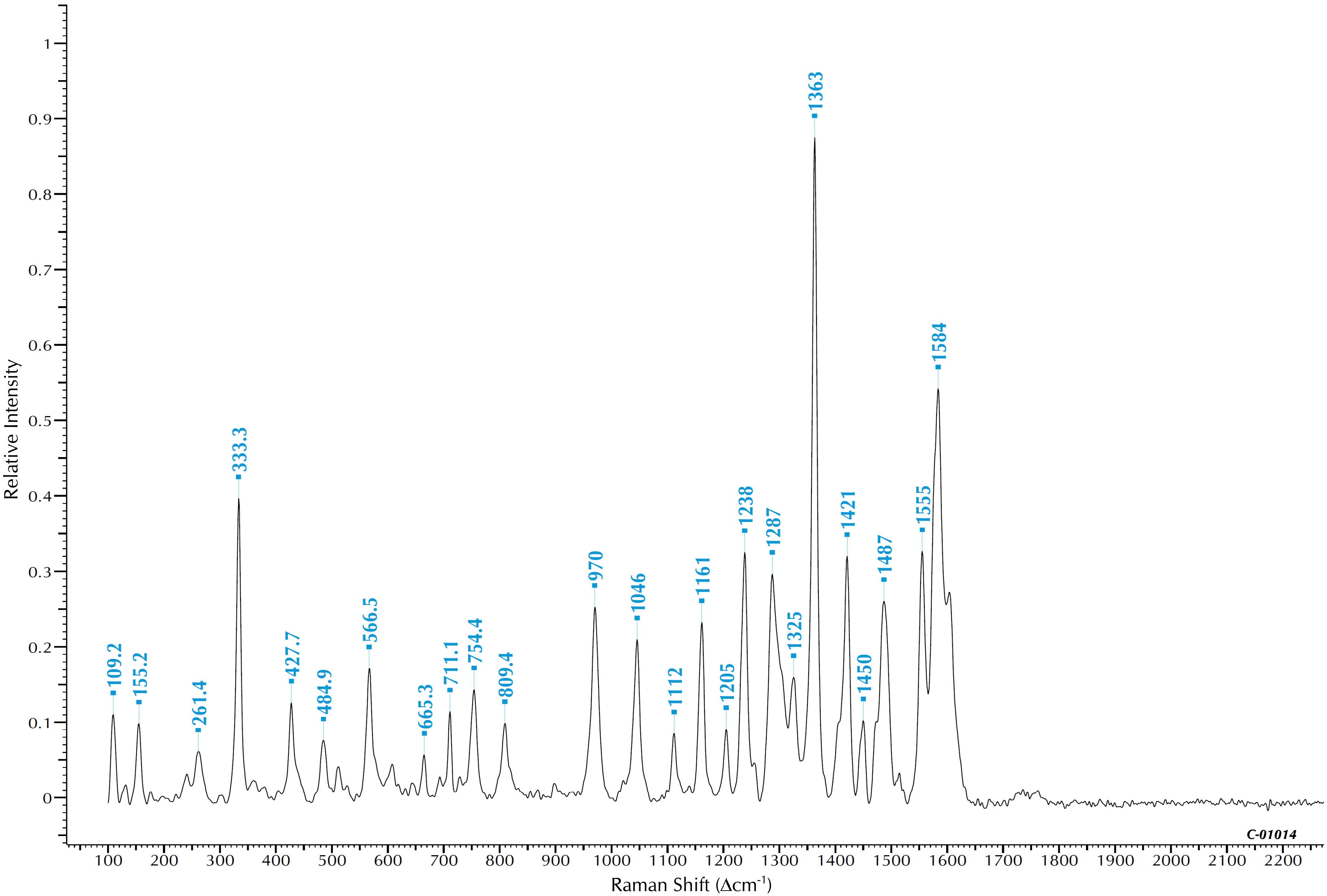
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12477;

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 214



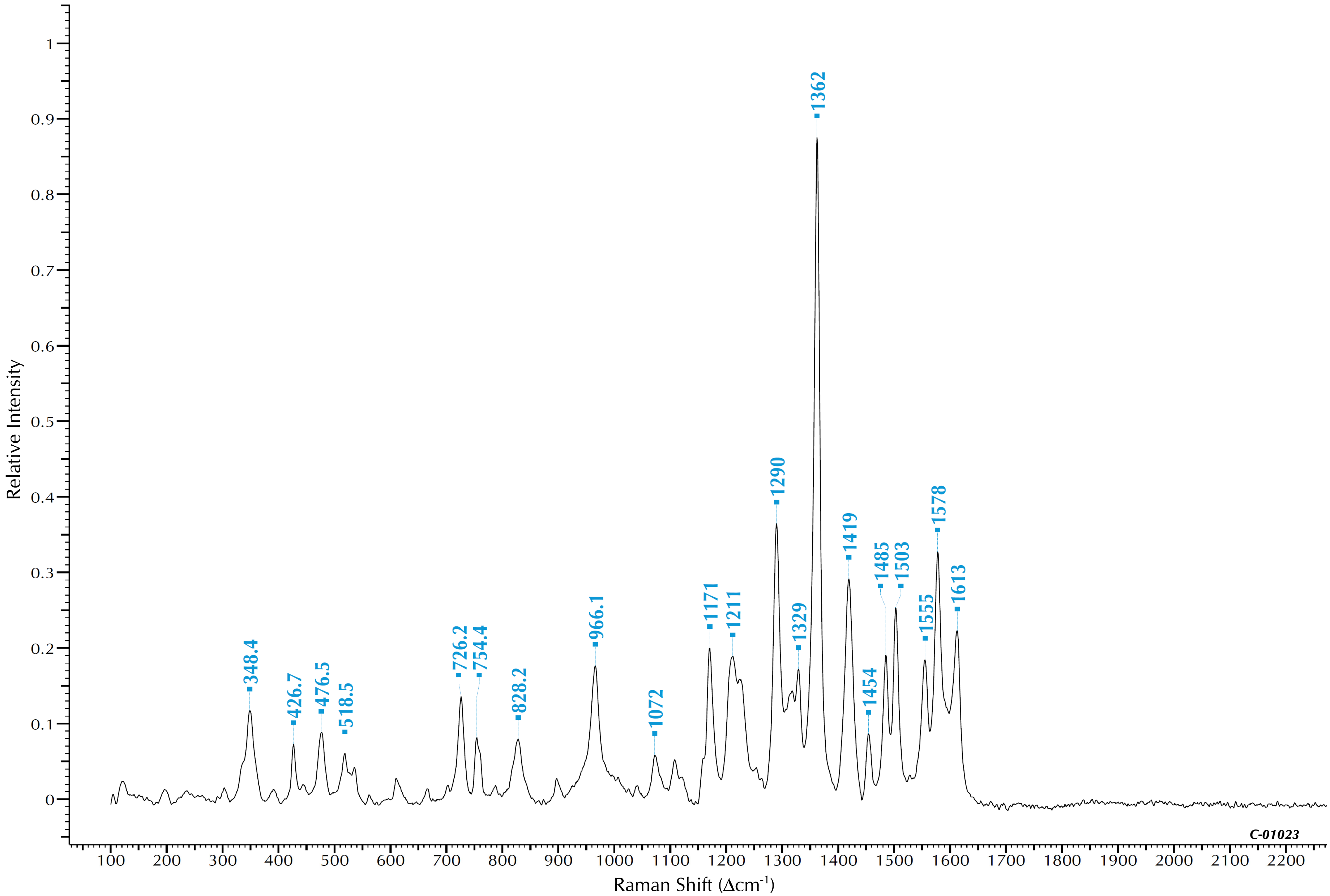
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 200660

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 220



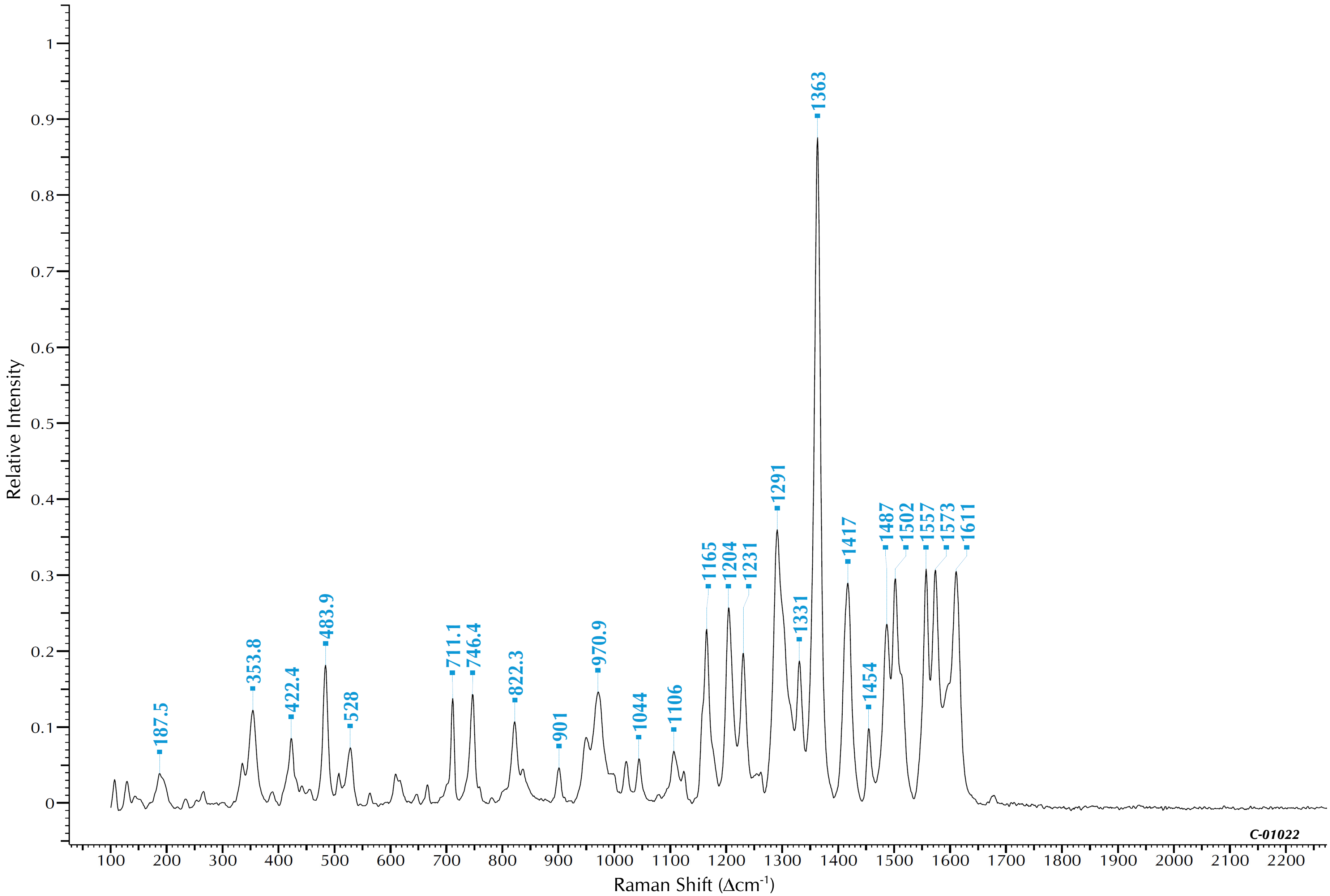
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20055

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 221



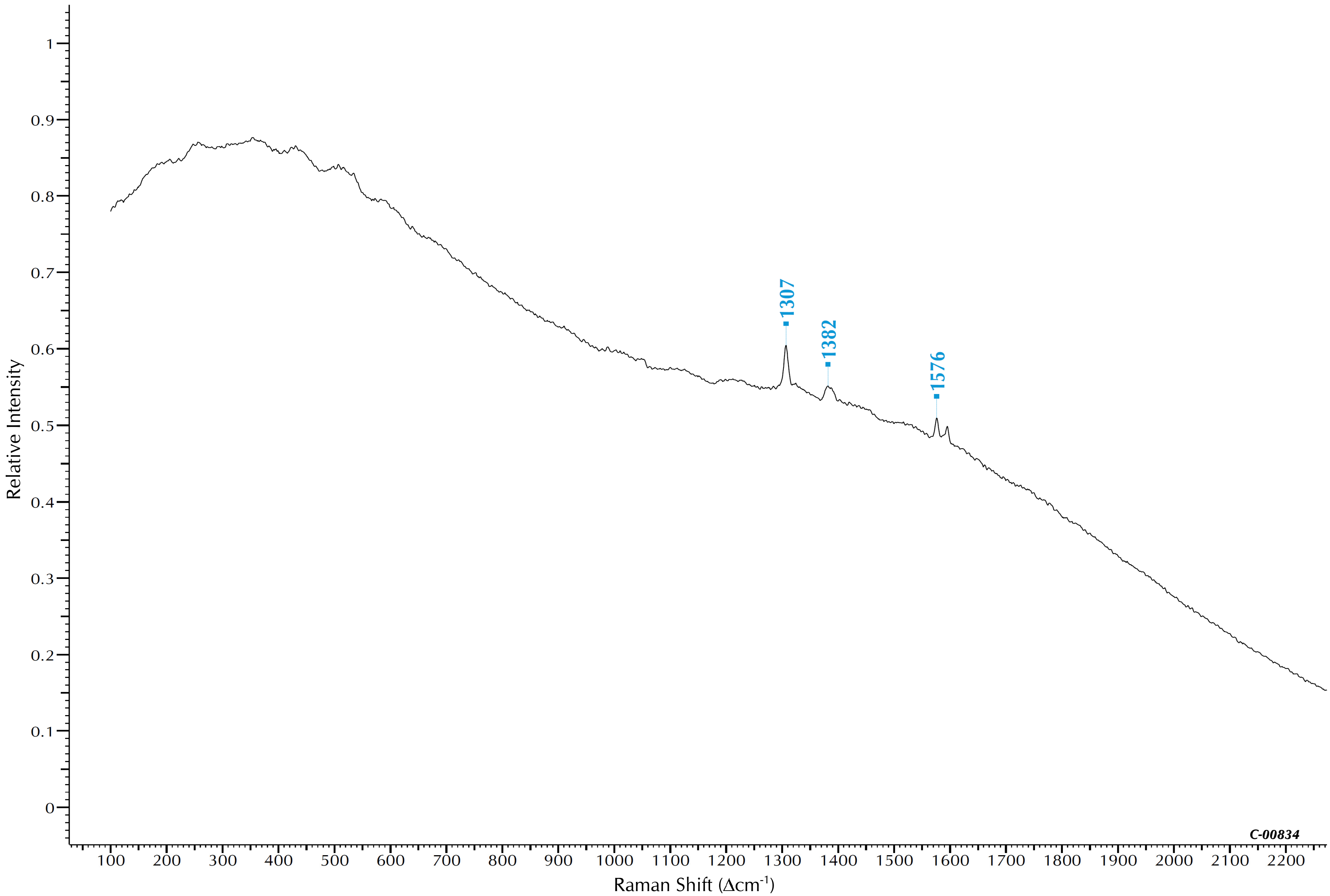
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20065

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 224



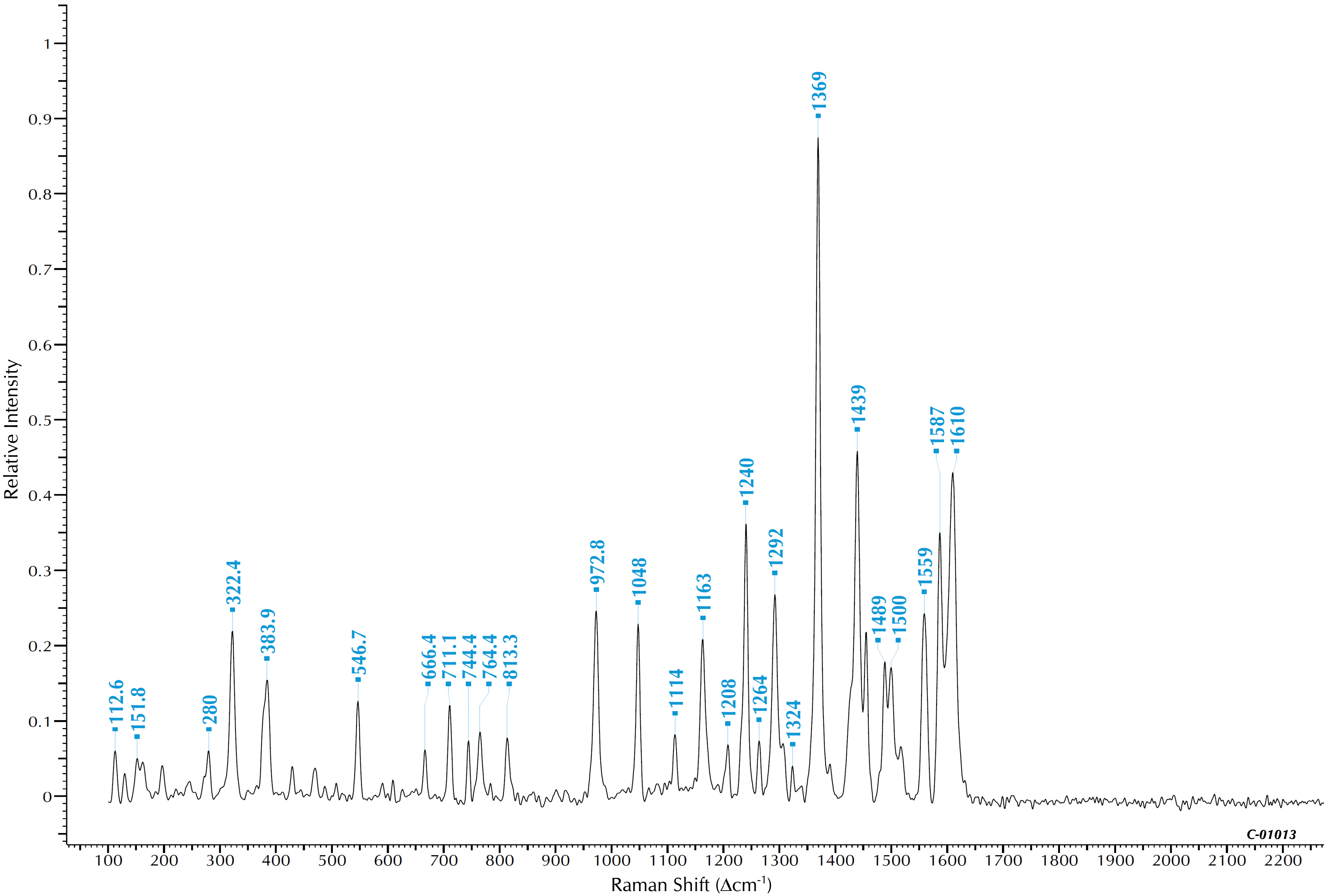
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71127

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Red 242



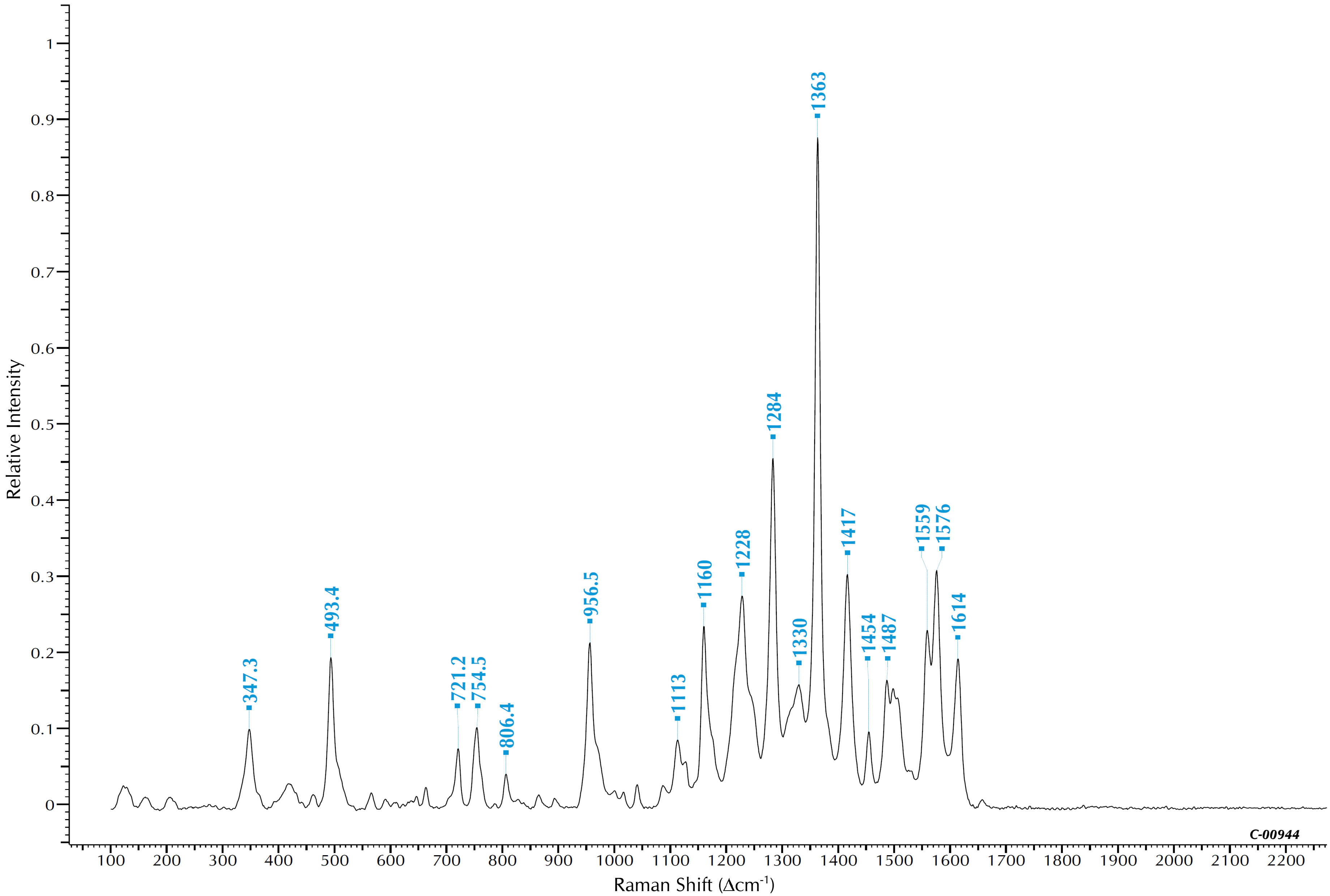
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20067

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 247



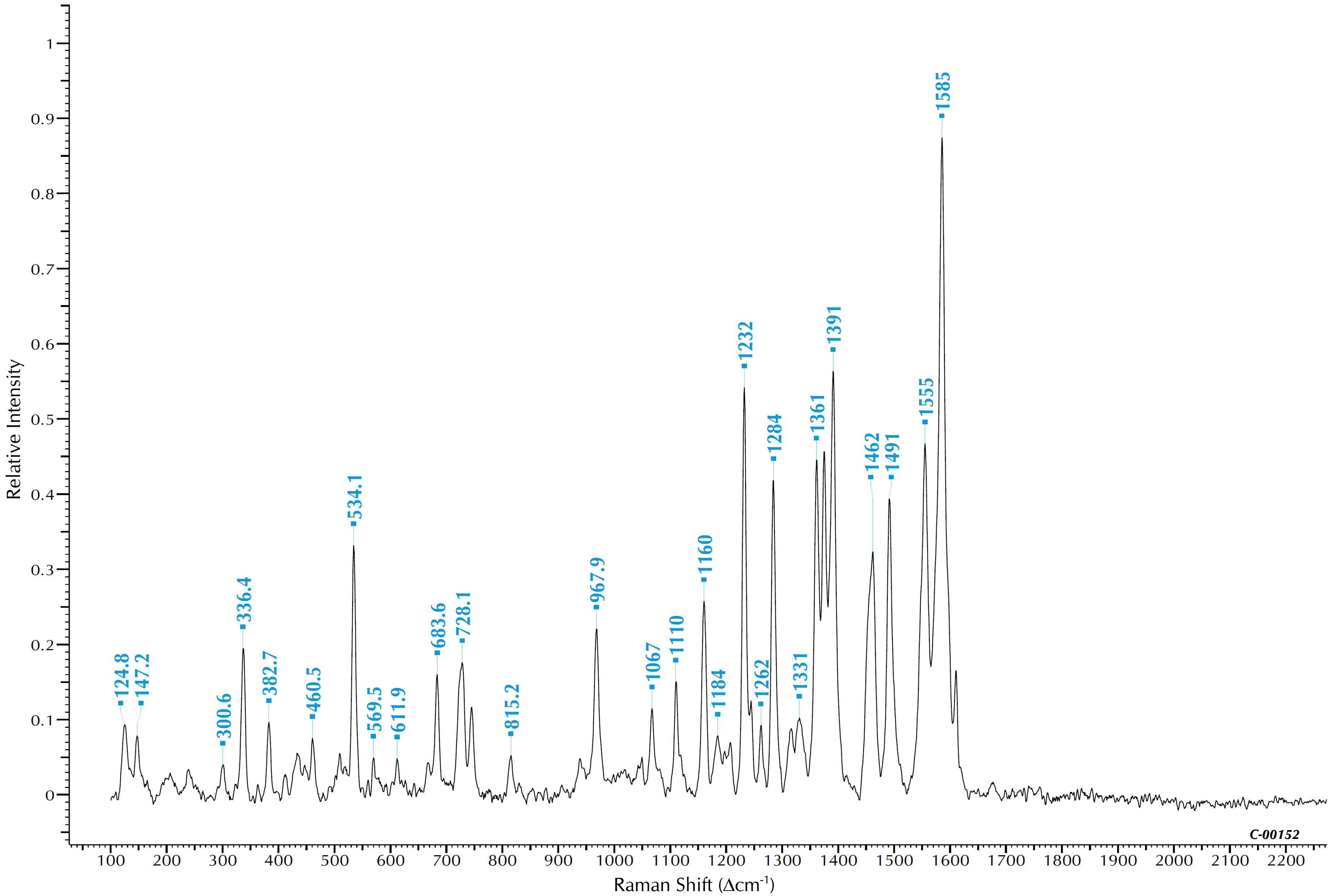
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Naphthol AS Lakes
Constitution Number: 15915

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 253



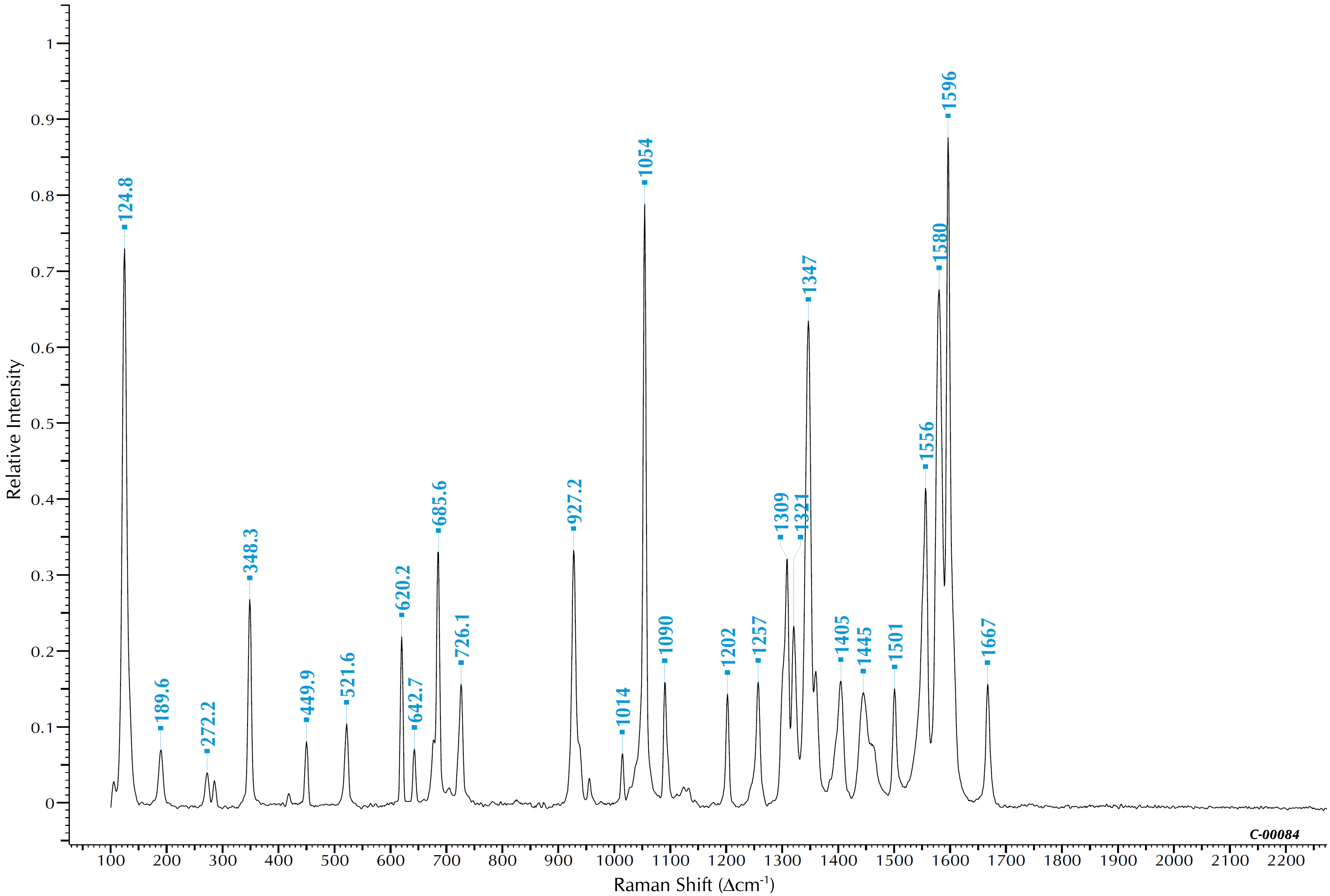
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12375

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Red 254 (α)



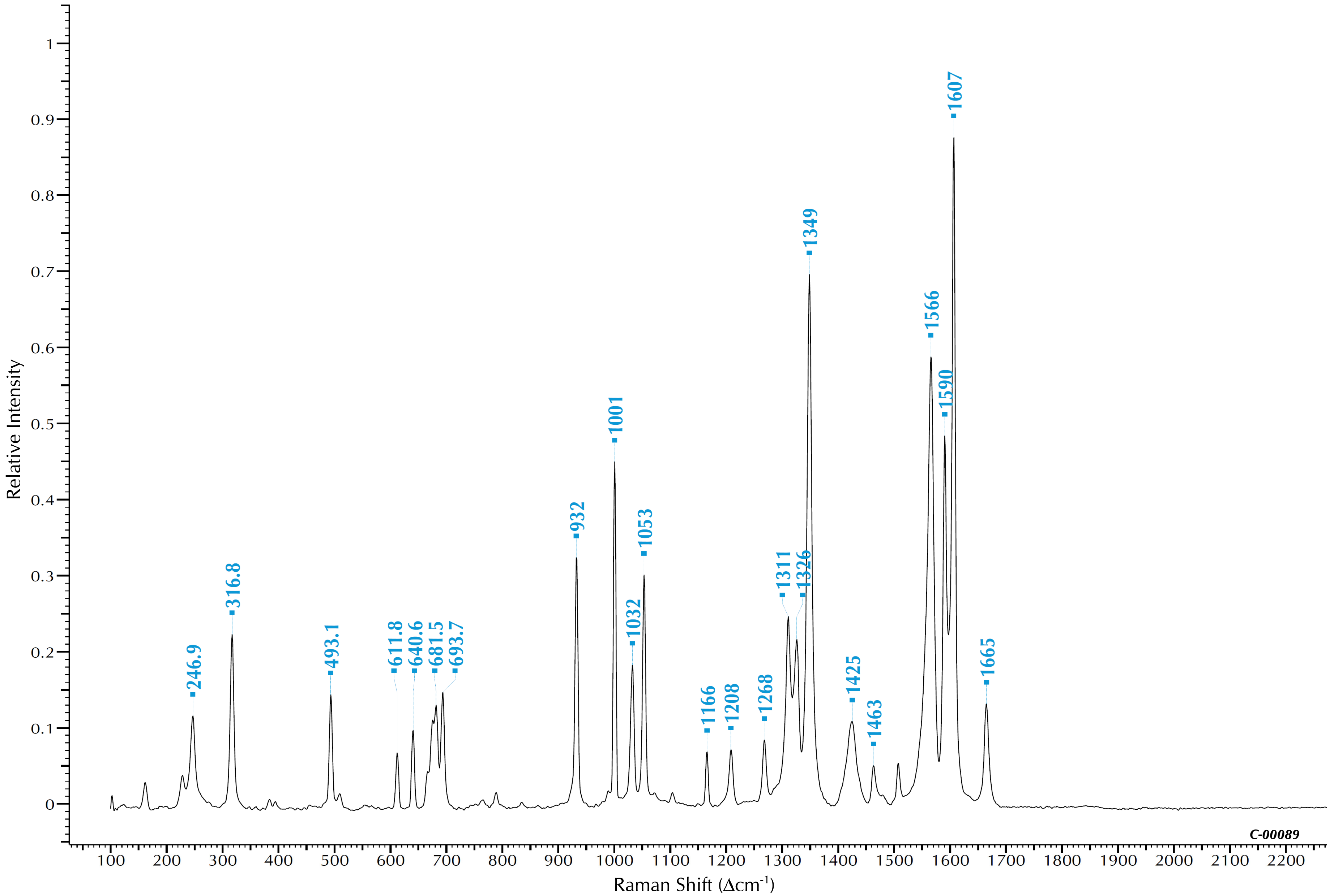
Chemical Category: Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)
Constitution Number: 56110

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 4

Microtrace LLC

C.I. Pigment Red 255



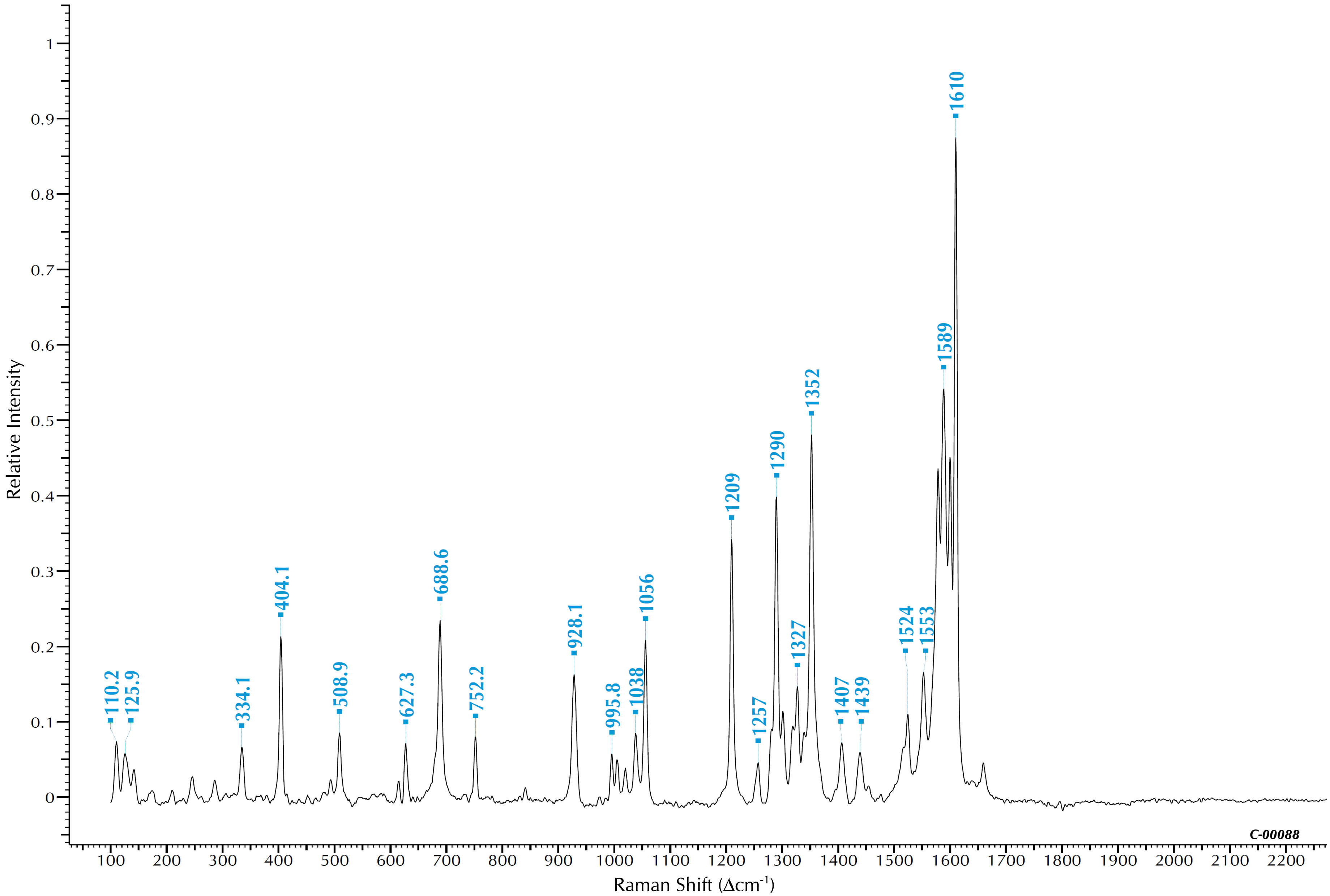
Chemical Category: Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)
Constitution Number: 561050

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 264



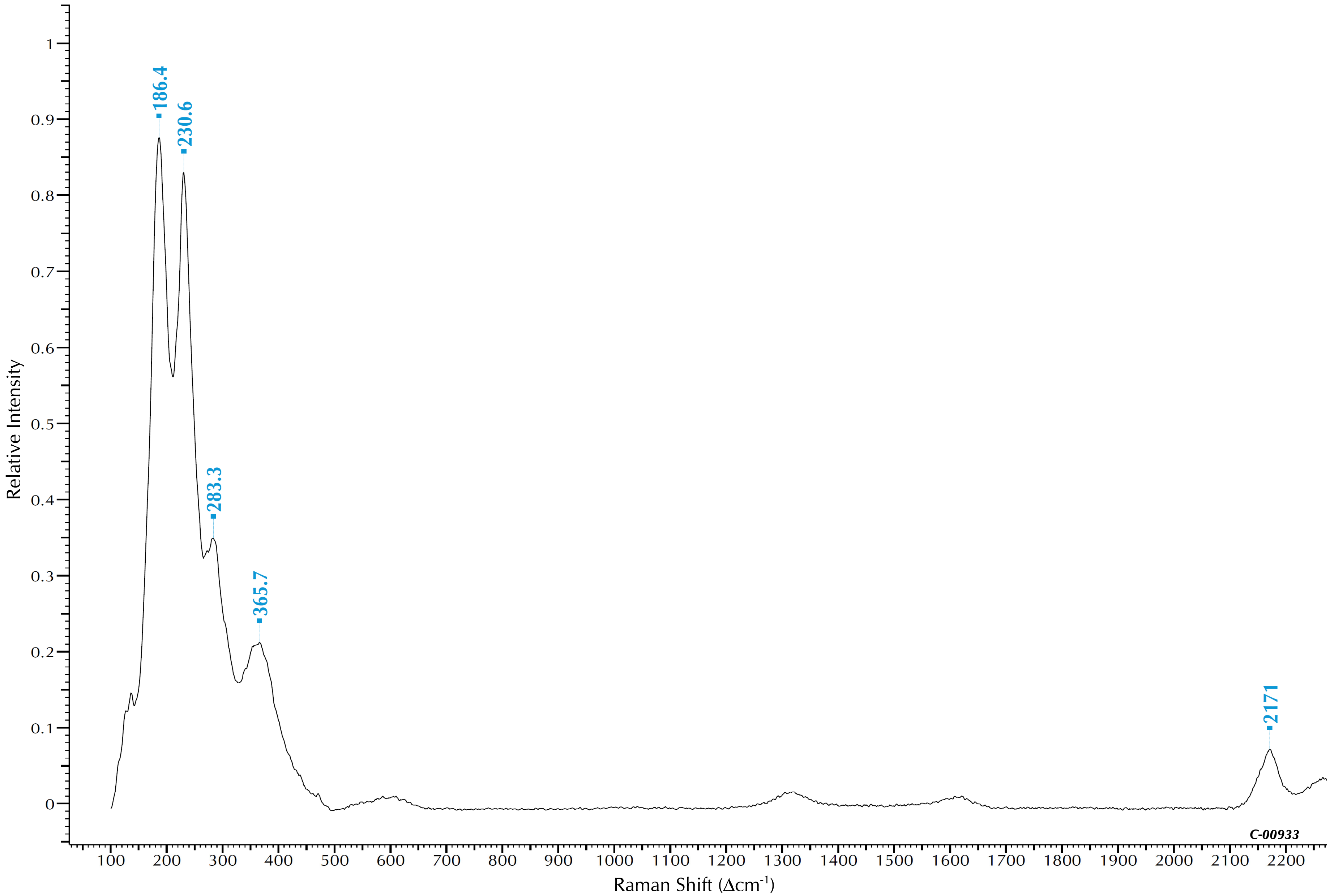
Chemical Category: Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)
Constitution Number: 561300

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Red 265



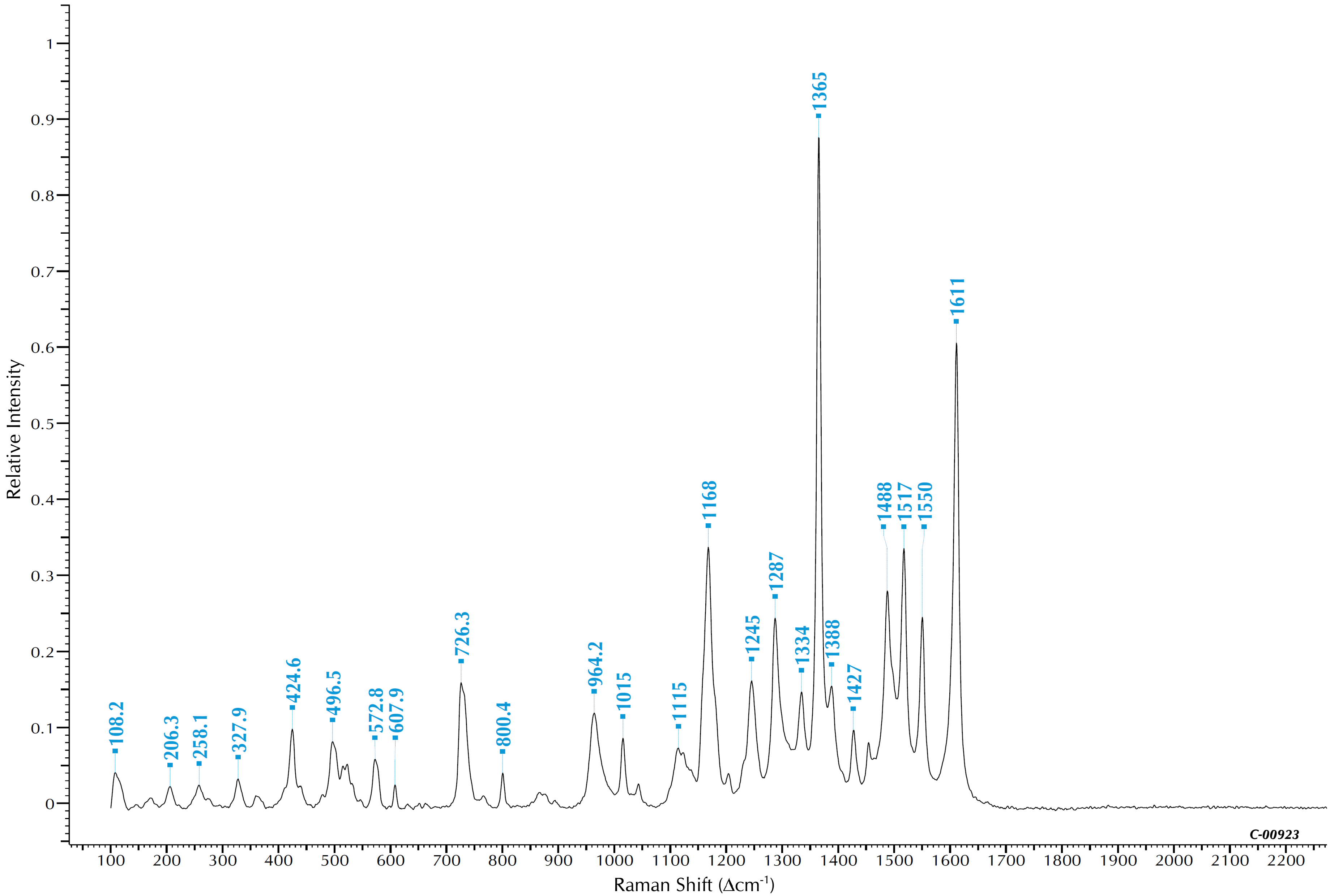
Chemical Category: Inorganic - Sulfide
Constitution Number: 77283:2

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 266



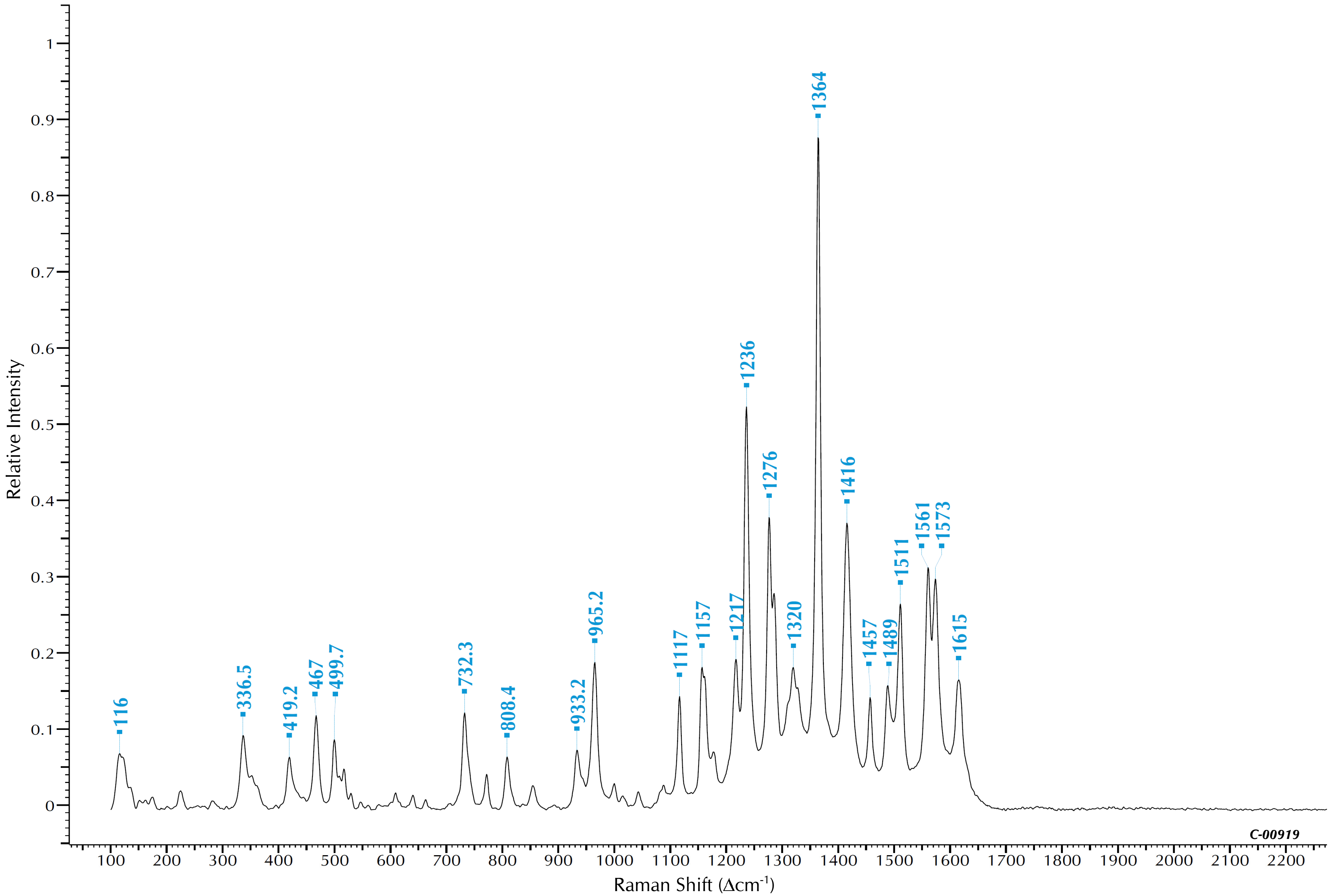
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12474

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 268



Chemical Category: Organic - Azo - Naphthol AS - Group 2

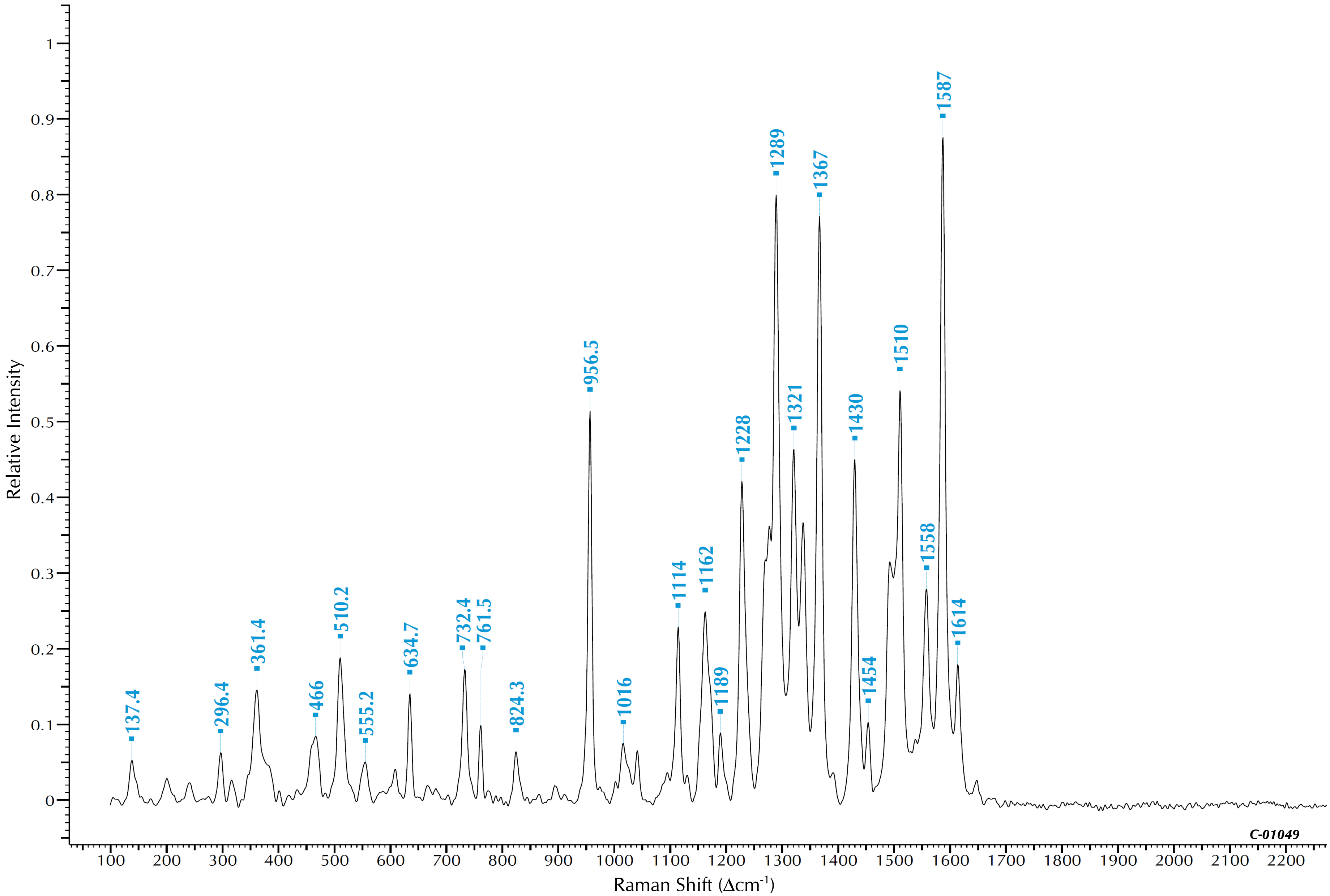
Constitution Number: 12316

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Red 269



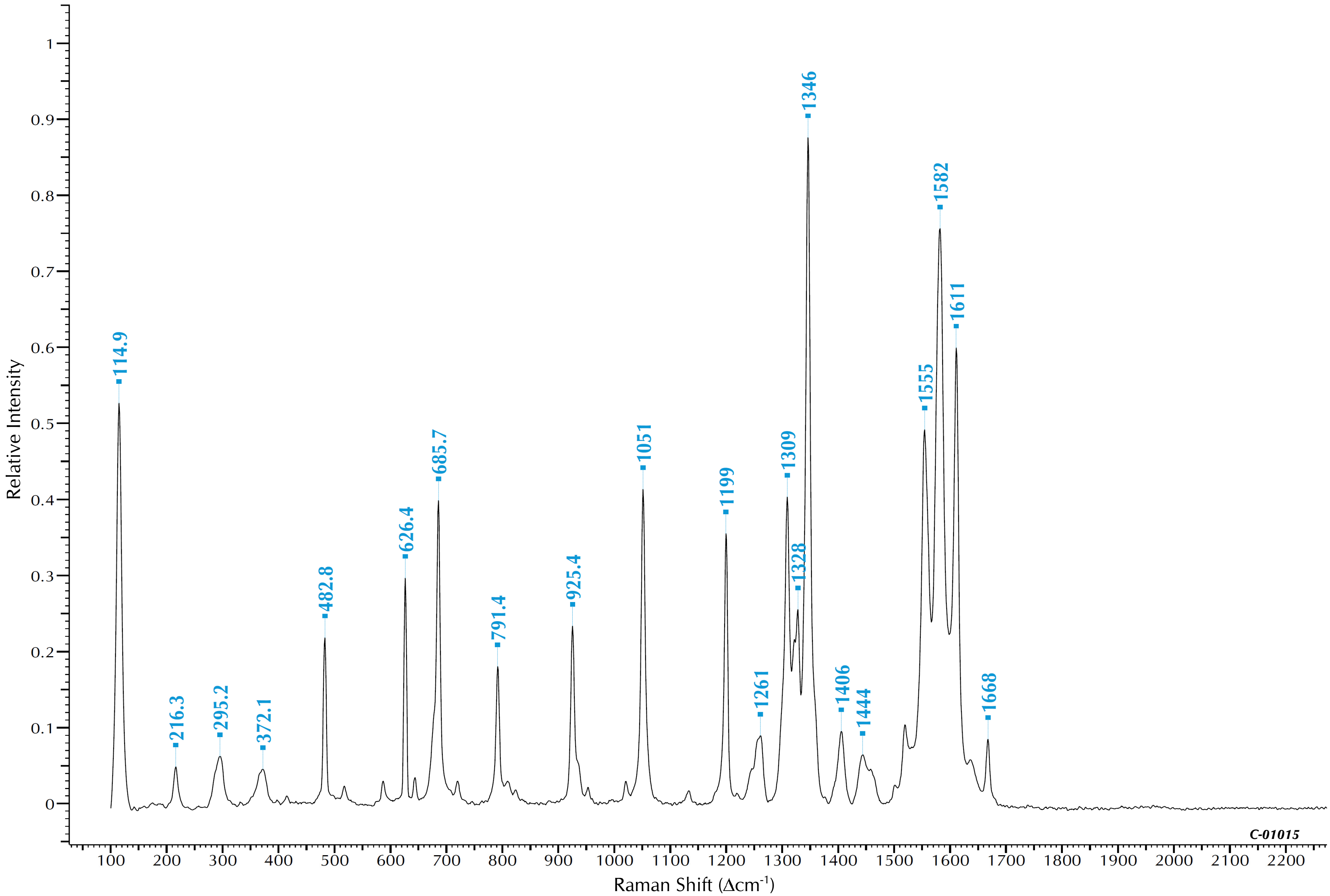
Chemical Category: Organic - Azo - Naphthol AS - Group 2
Constitution Number: 12466

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Red 272



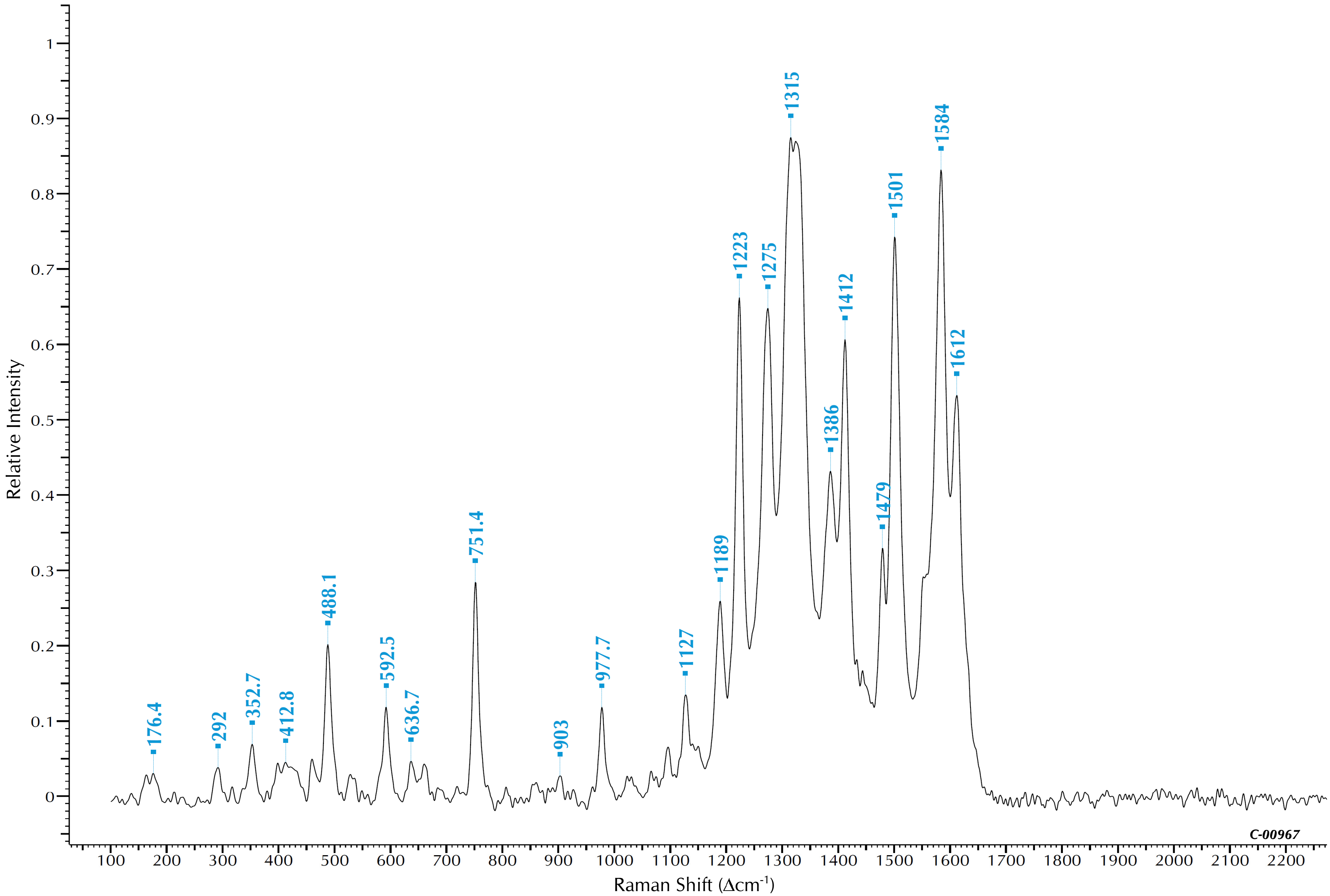
Chemical Category: Organic - Polycyclic - Dikeopyrrolo-Pyrrole (DPP)
Constitution Number: 561150

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Red 273



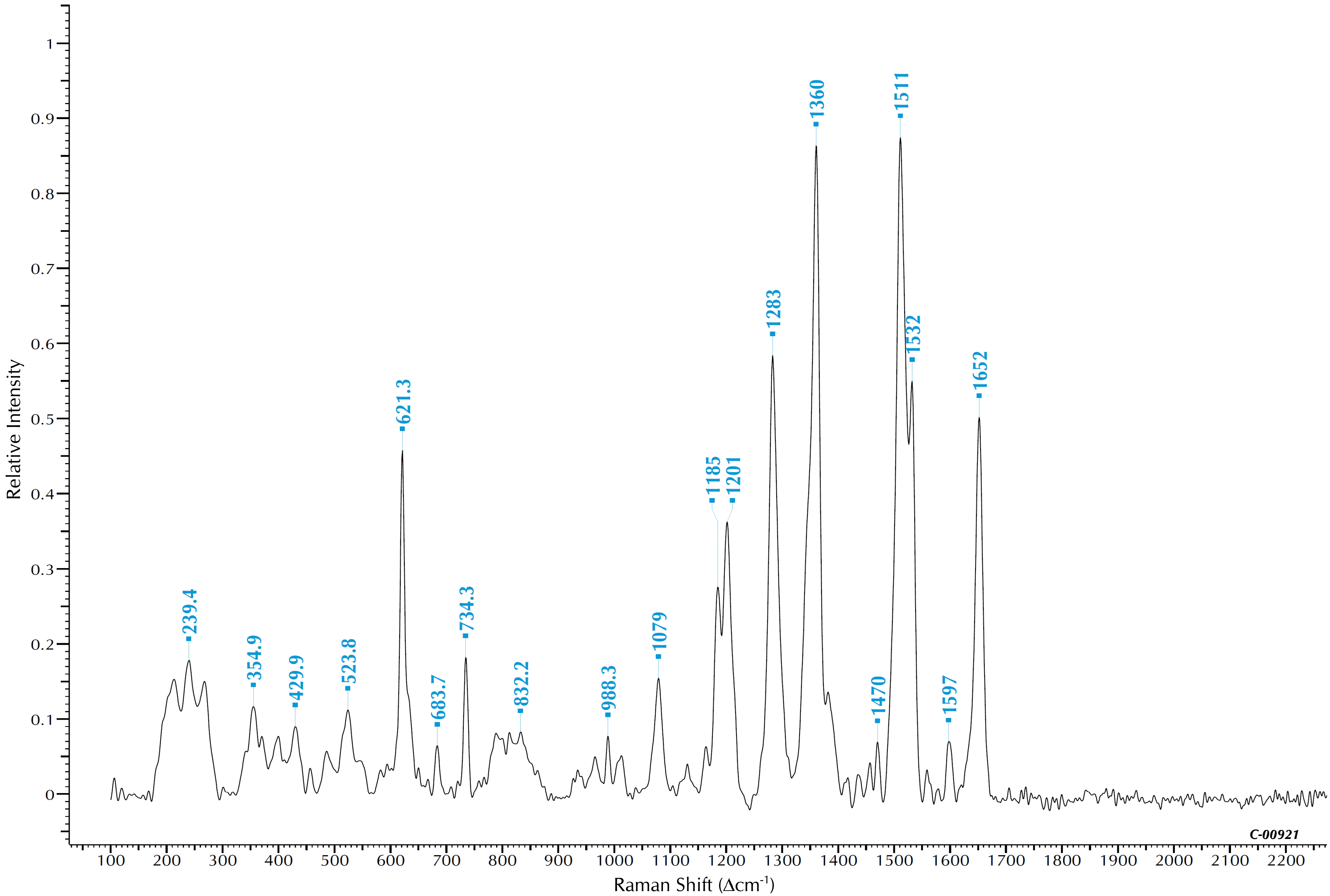
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Naphthalene Sulfonic Acid Lakes
Constitution Number: 16035:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Violet 1



Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions

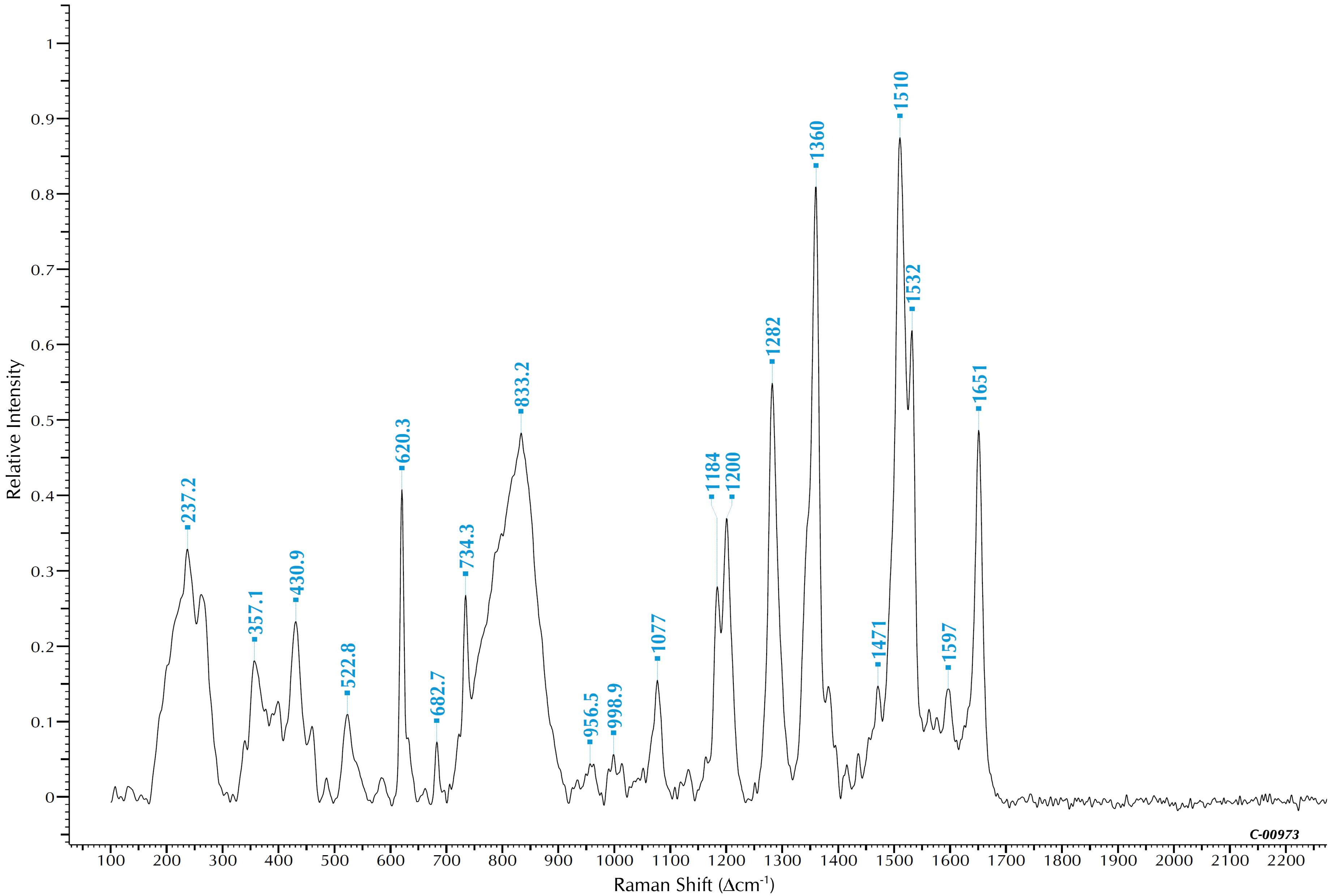
Constitution Number: 45170:2 12475

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Violet 1:X



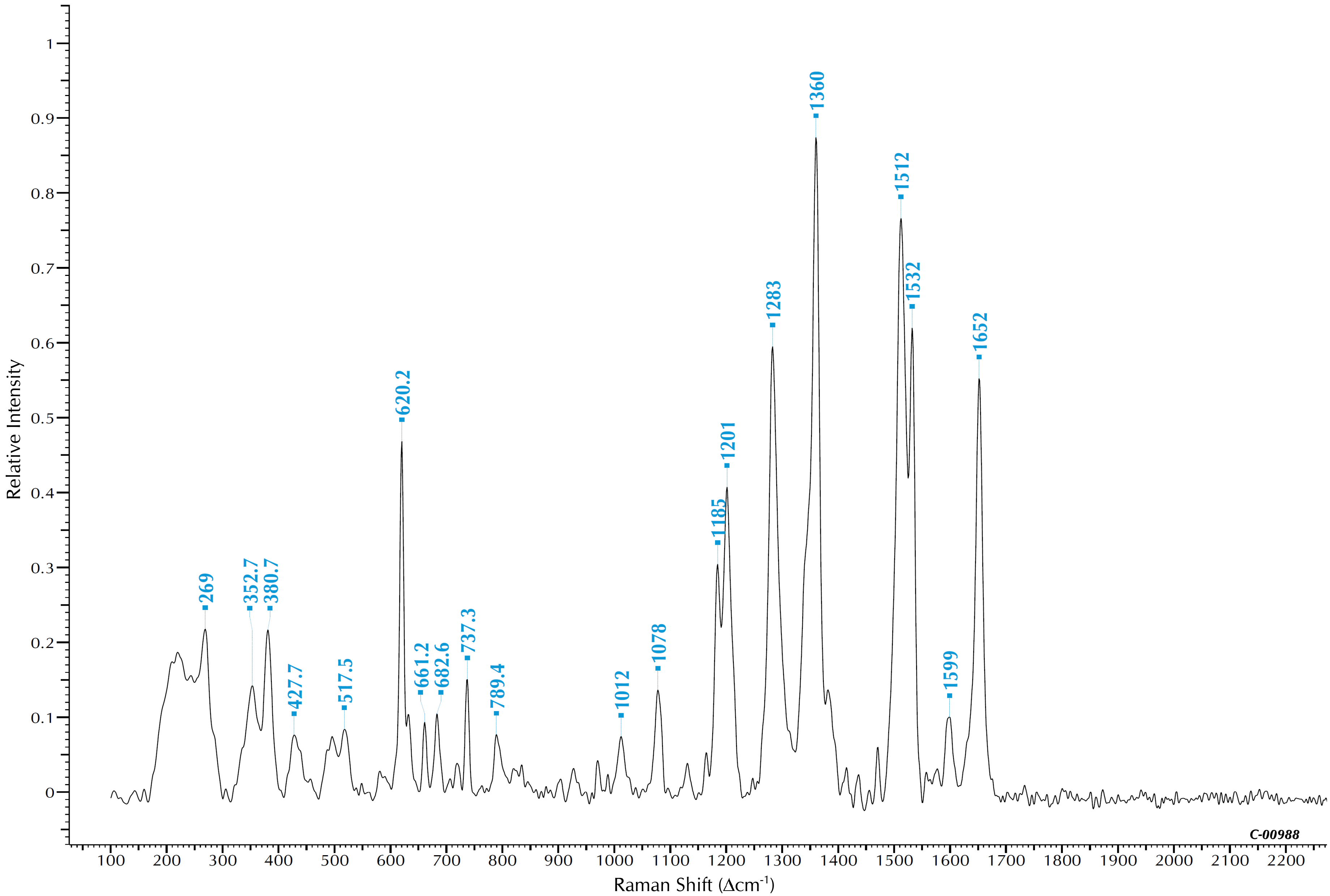
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45710:x

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Violet 2



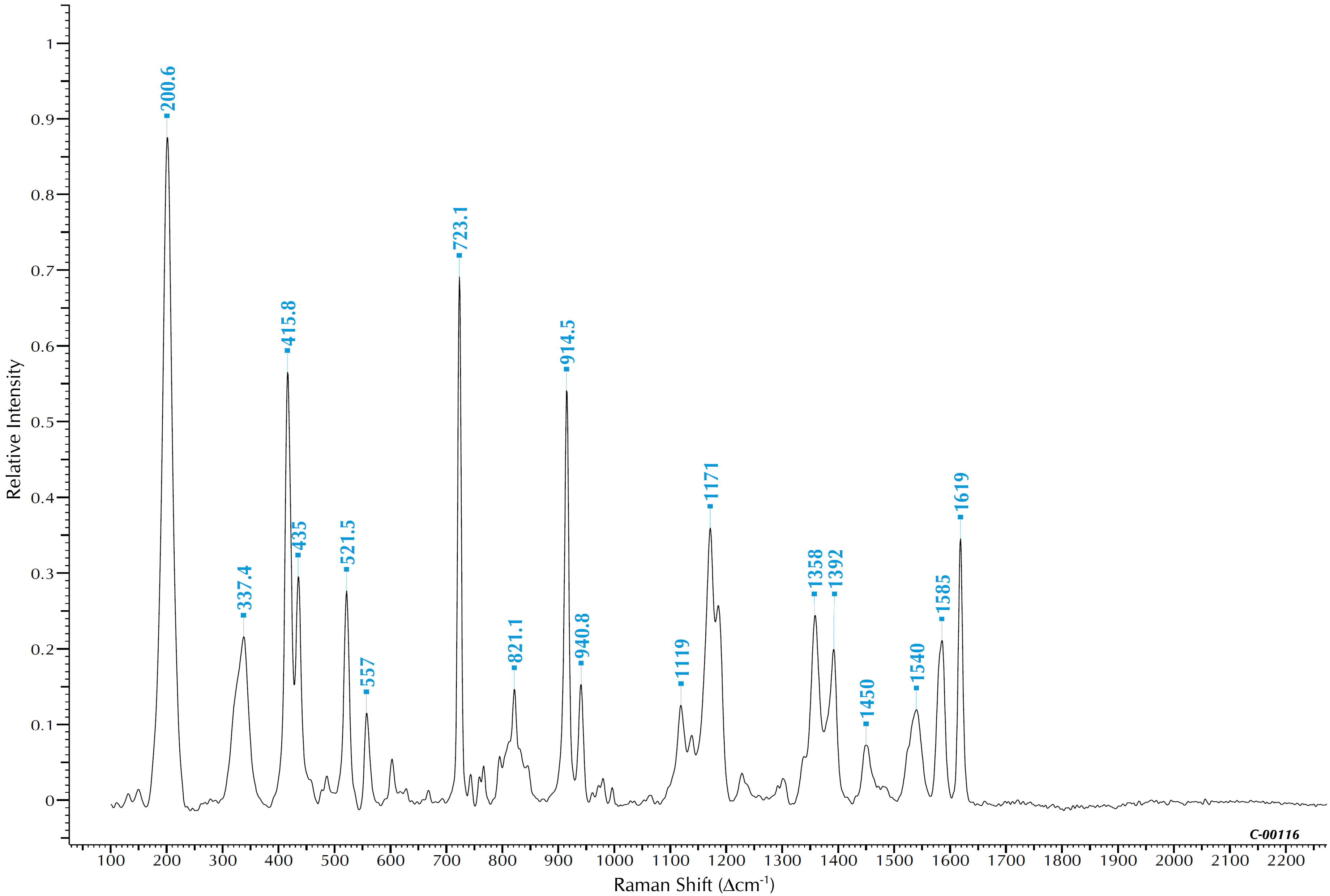
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 45175:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Violet 3



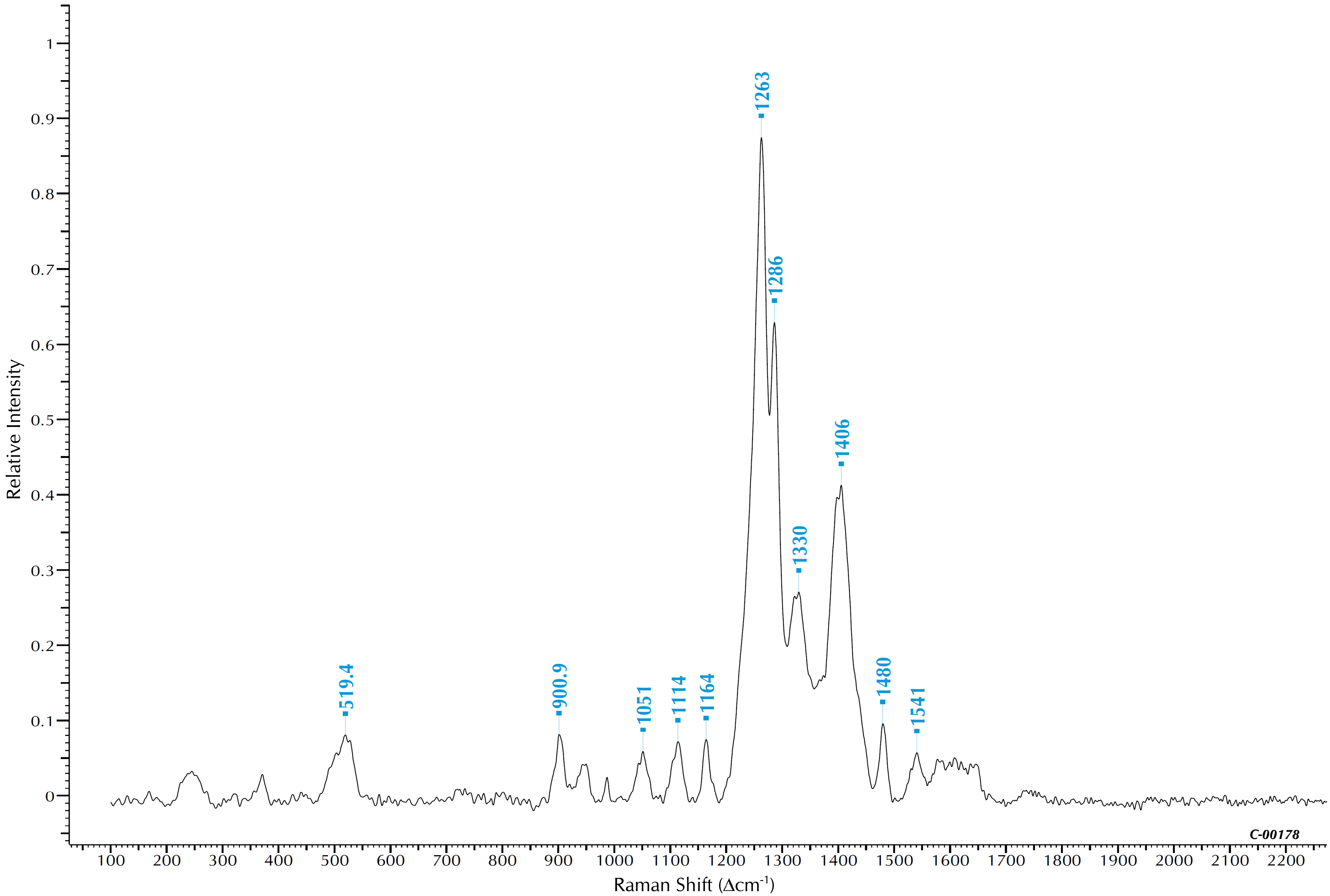
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42535

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 5

Microtrace LLC

C.I. Pigment Violet 5:1



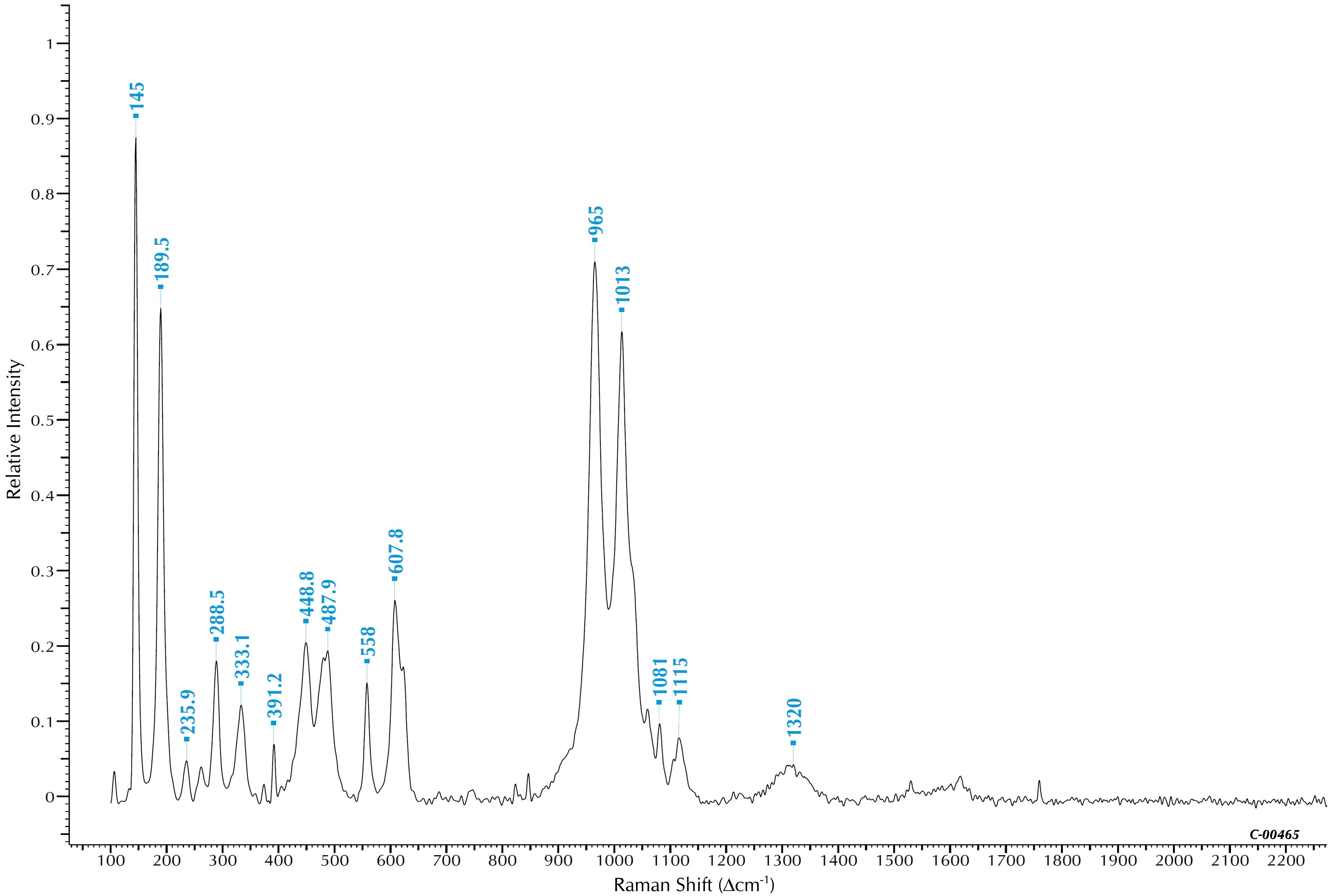
Chemical Category: Organic - Polycyclic - Hydroxyanthraquinone
Constitution Number: 58055:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Violet 14



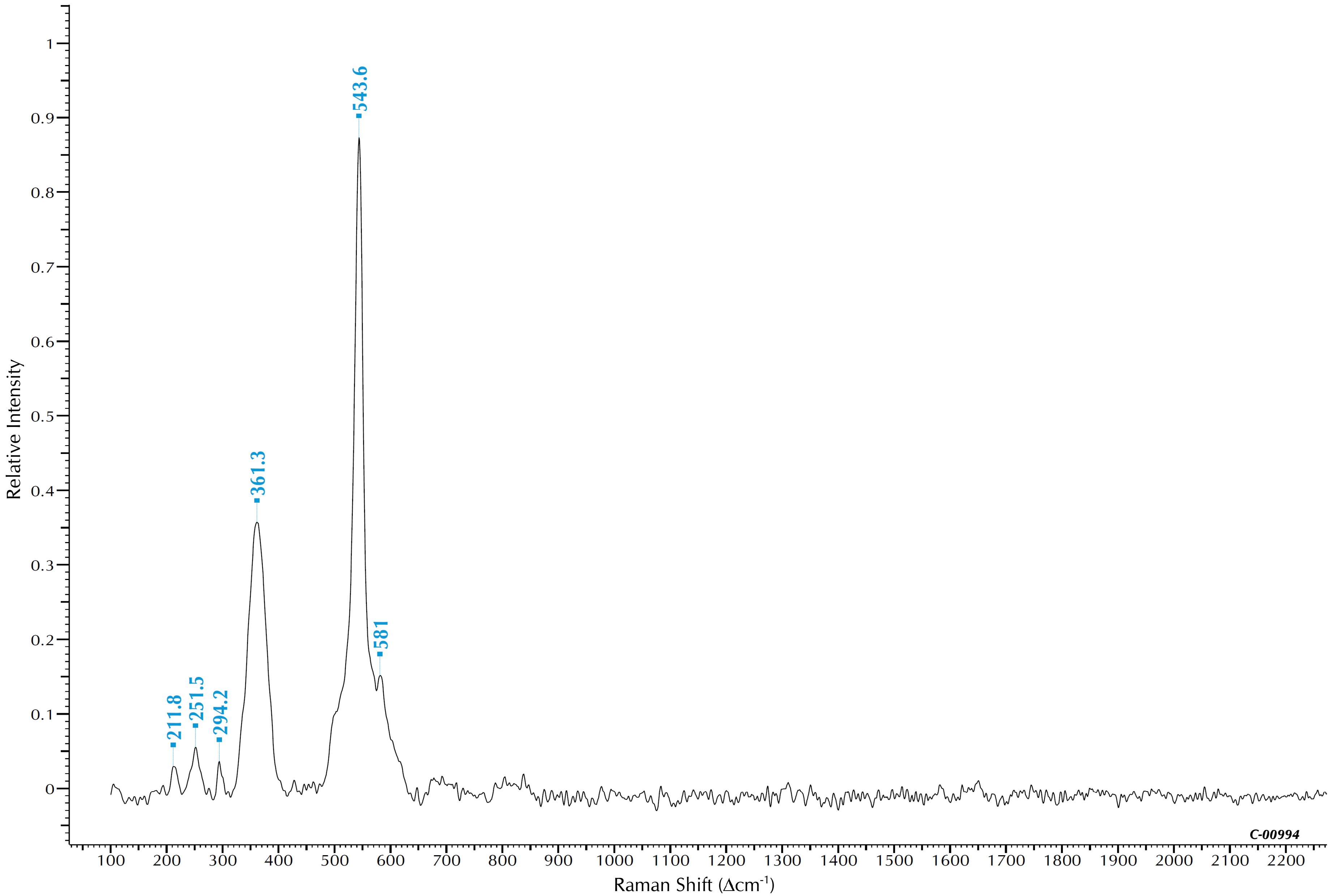
Chemical Category: Inorganic - Hydroxide
Constitution Number: 77360

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 4

Microtrace LLC

C.I. Pigment Violet 15



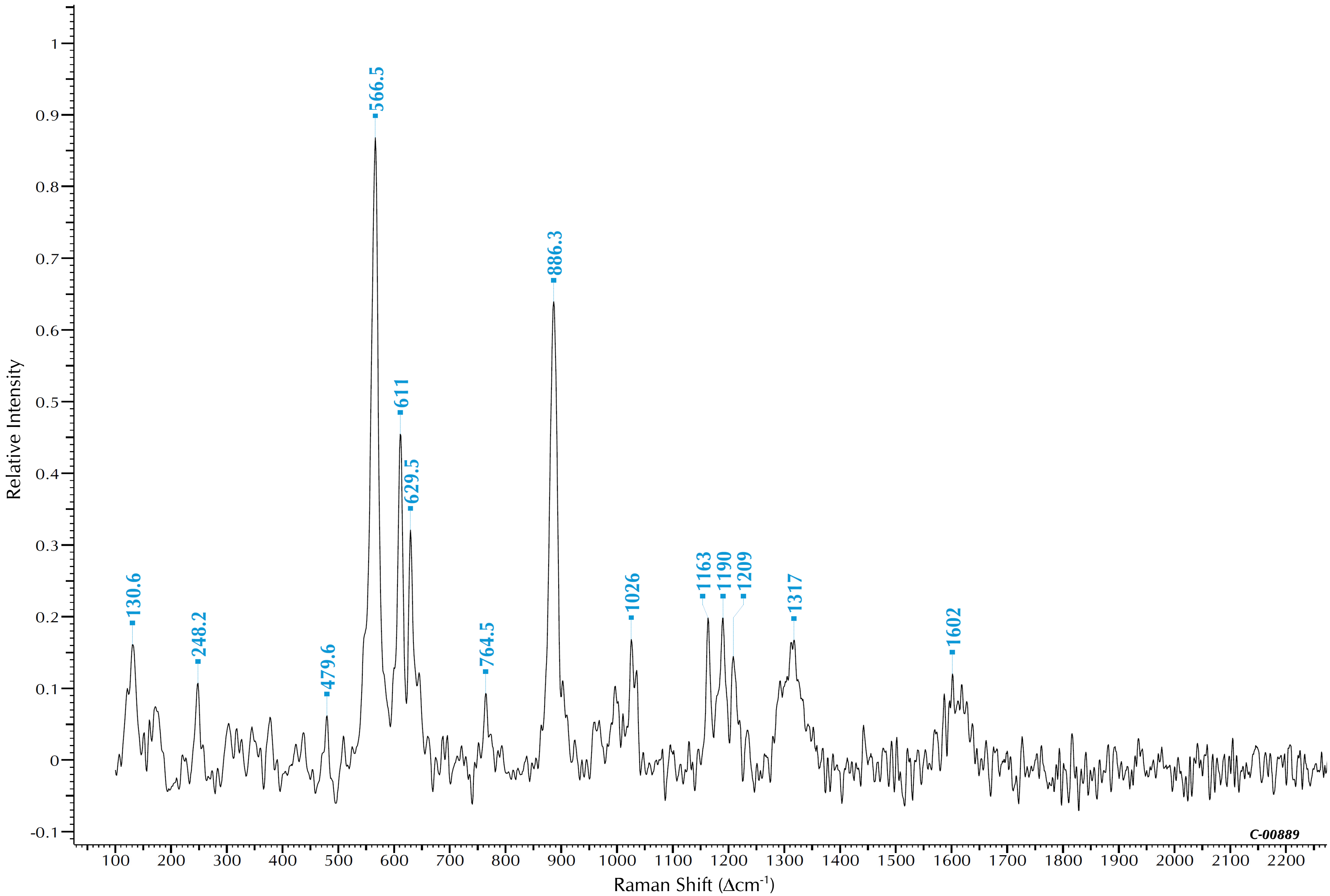
Chemical Category: Inorganic - Sulfide
Constitution Number: 77007

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 1

Microtrace LLC

C.I. Pigment Violet 16



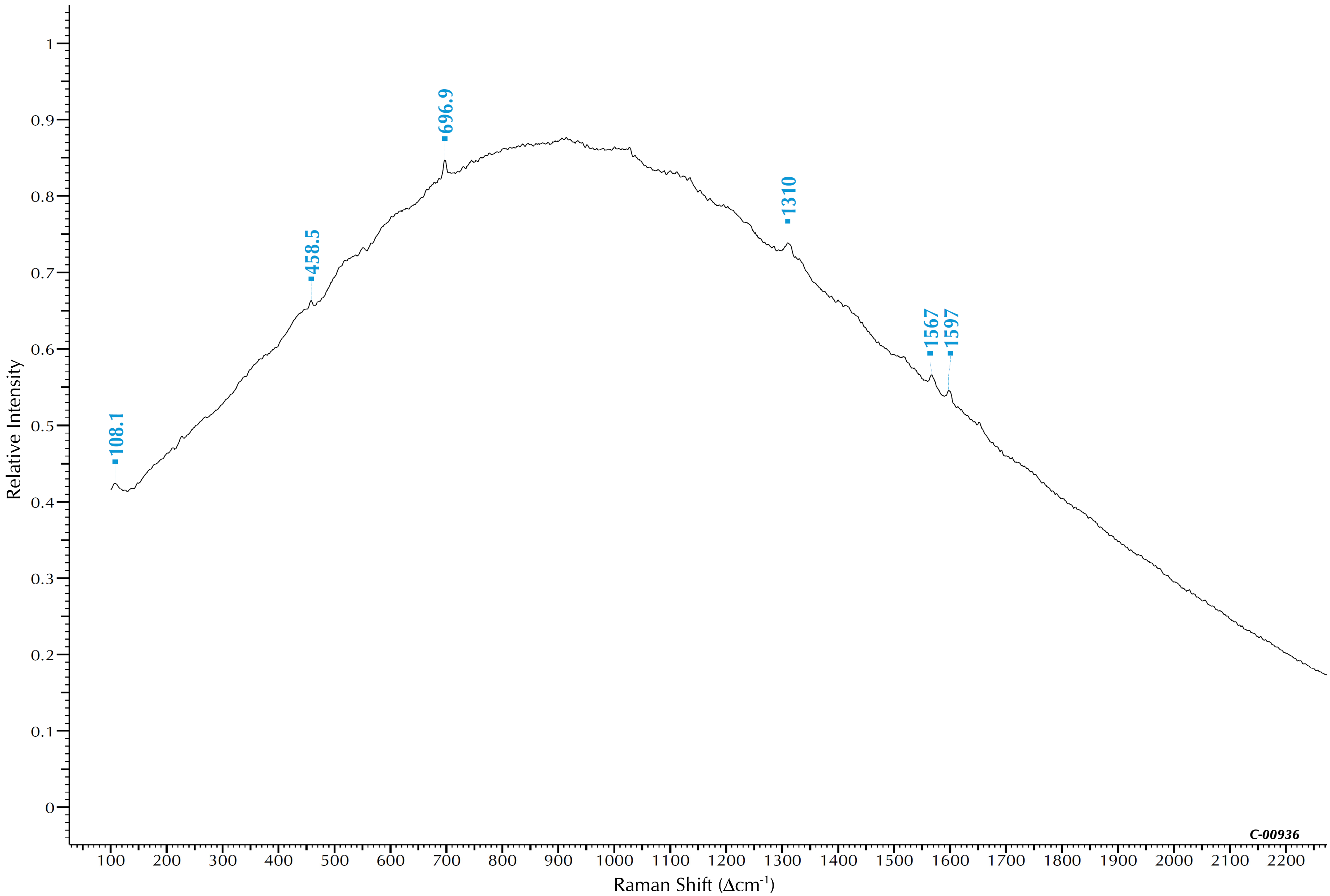
Chemical Category: Inorganic - Phosphate
Constitution Number: 77742

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Violet 19 (β)



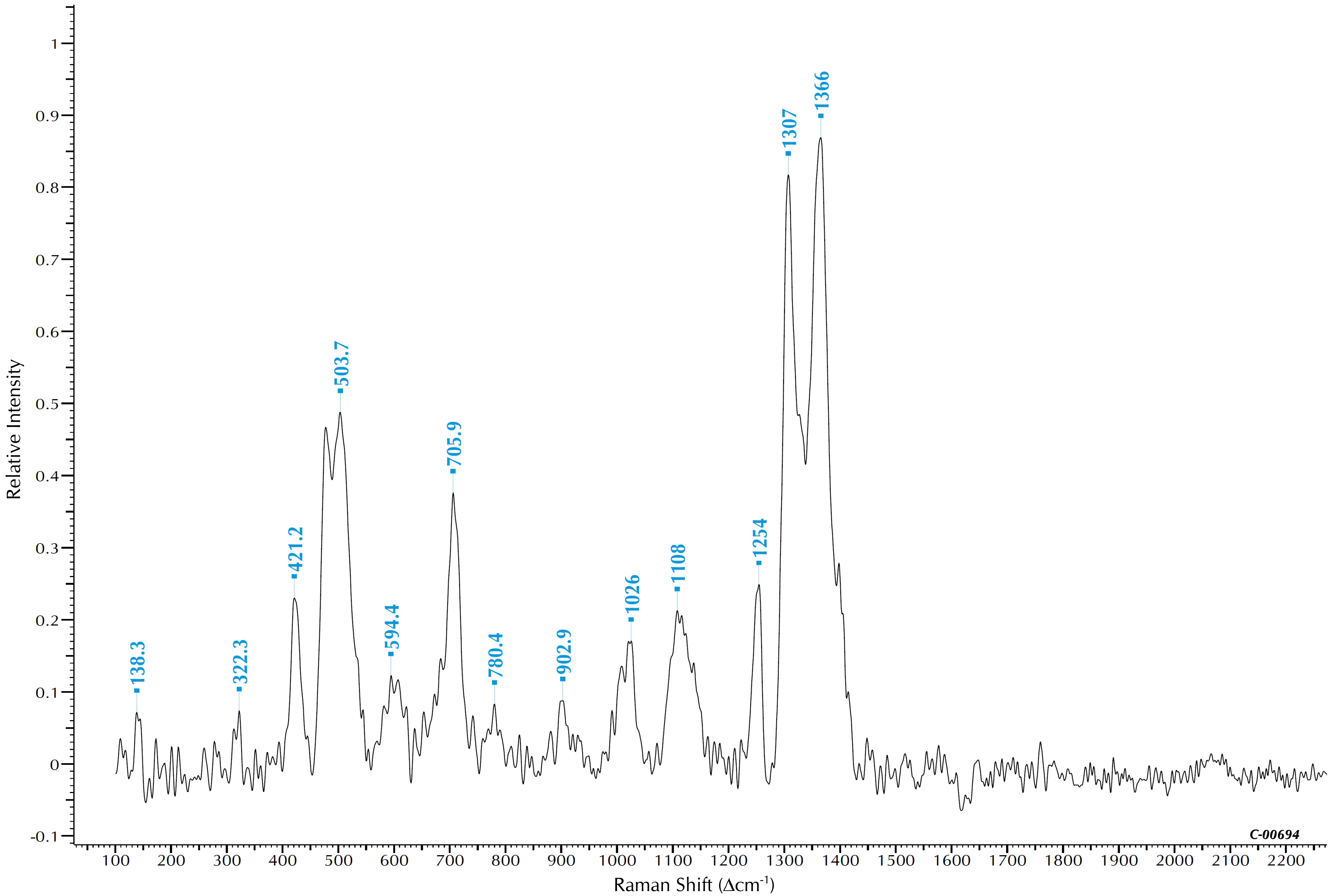
Chemical Category: Organic - Polycyclic - Quinacridone
Constitution Number: 73900

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 1

Microtrace LLC

C.I. Pigment Violet 23 (α (tentative))



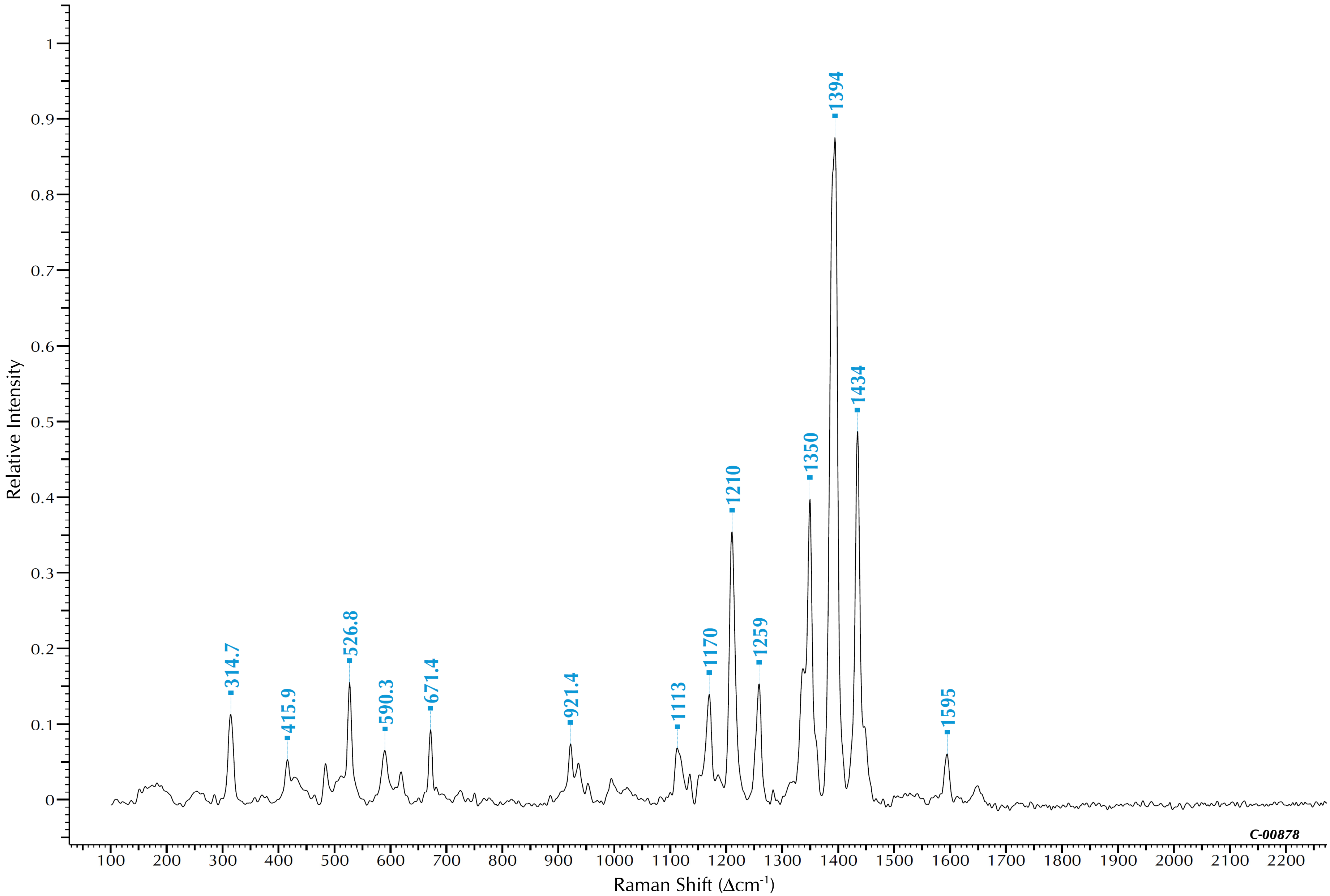
Chemical Category: Organic - Polycyclic - Dioxazine
Constitution Number: 51319

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 4

Microtrace LLC

C.I. Pigment Violet 23 (β)



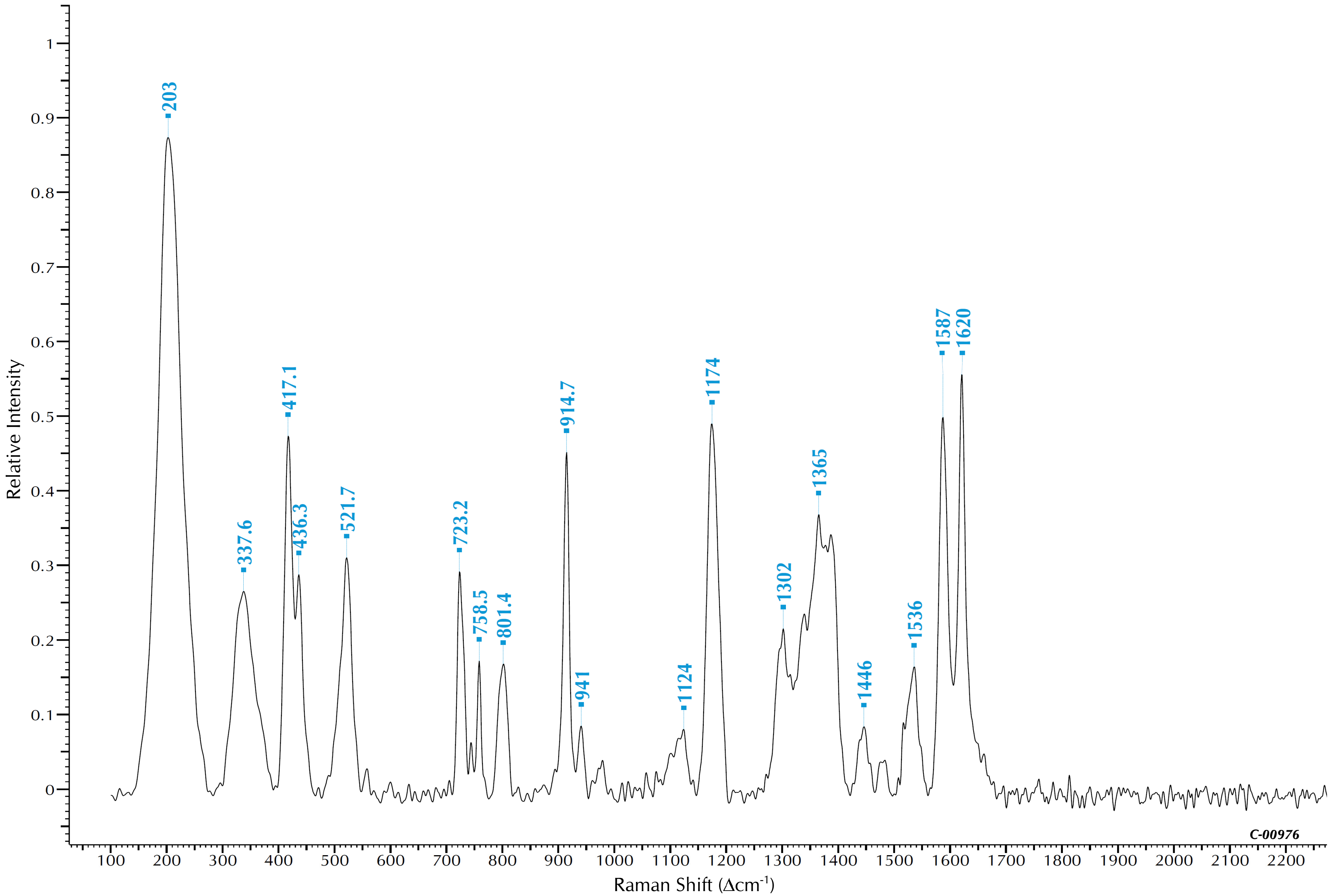
Chemical Category: Organic - Polycyclic - Dioxazine
Constitution Number: 51319

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 2

Microtrace LLC

C.I. Pigment Violet 27



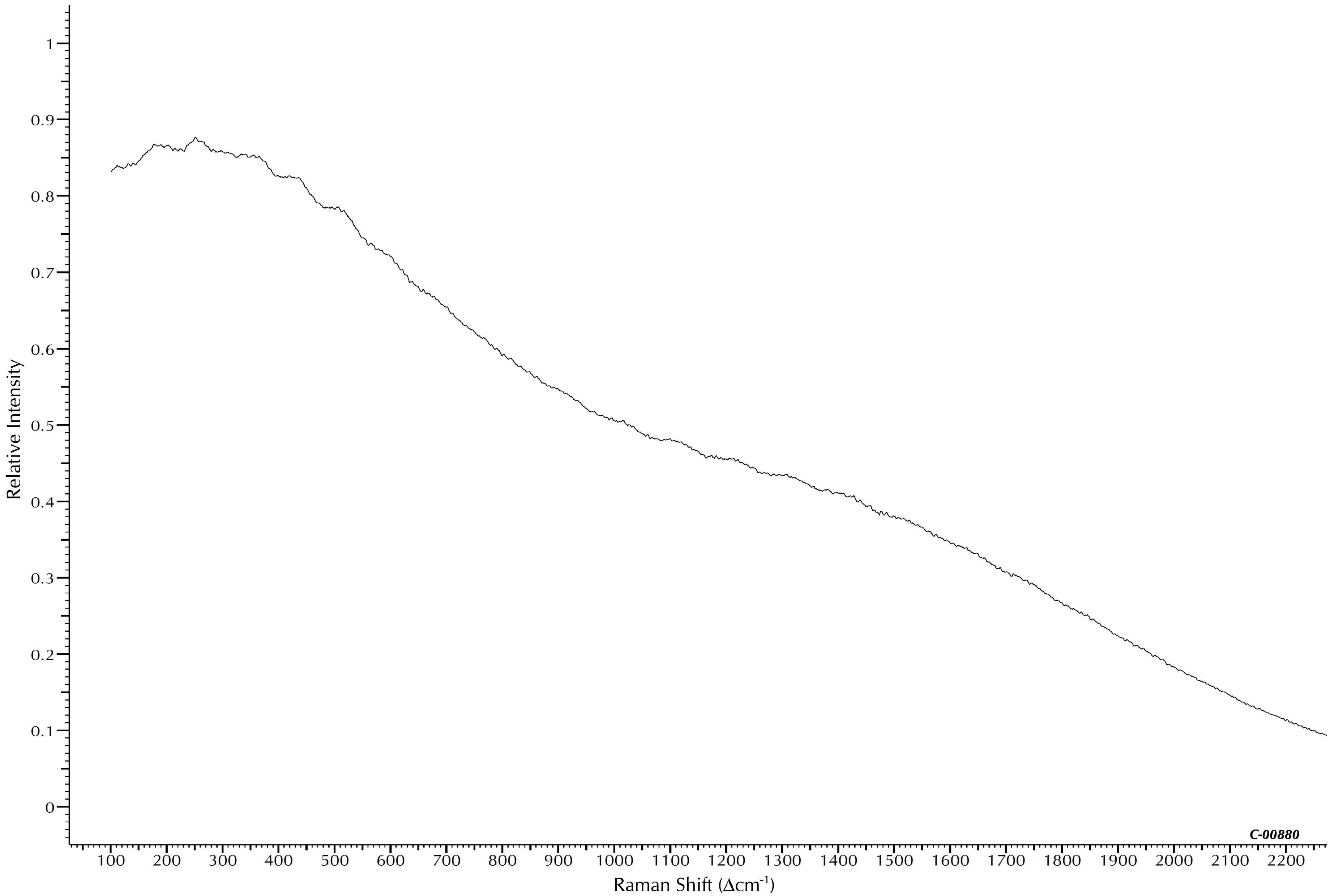
Chemical Category: Organic - Polycyclic - Triarylcarbonium - Dye salts with complex anions
Constitution Number: 42535:3 77510

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Violet 29



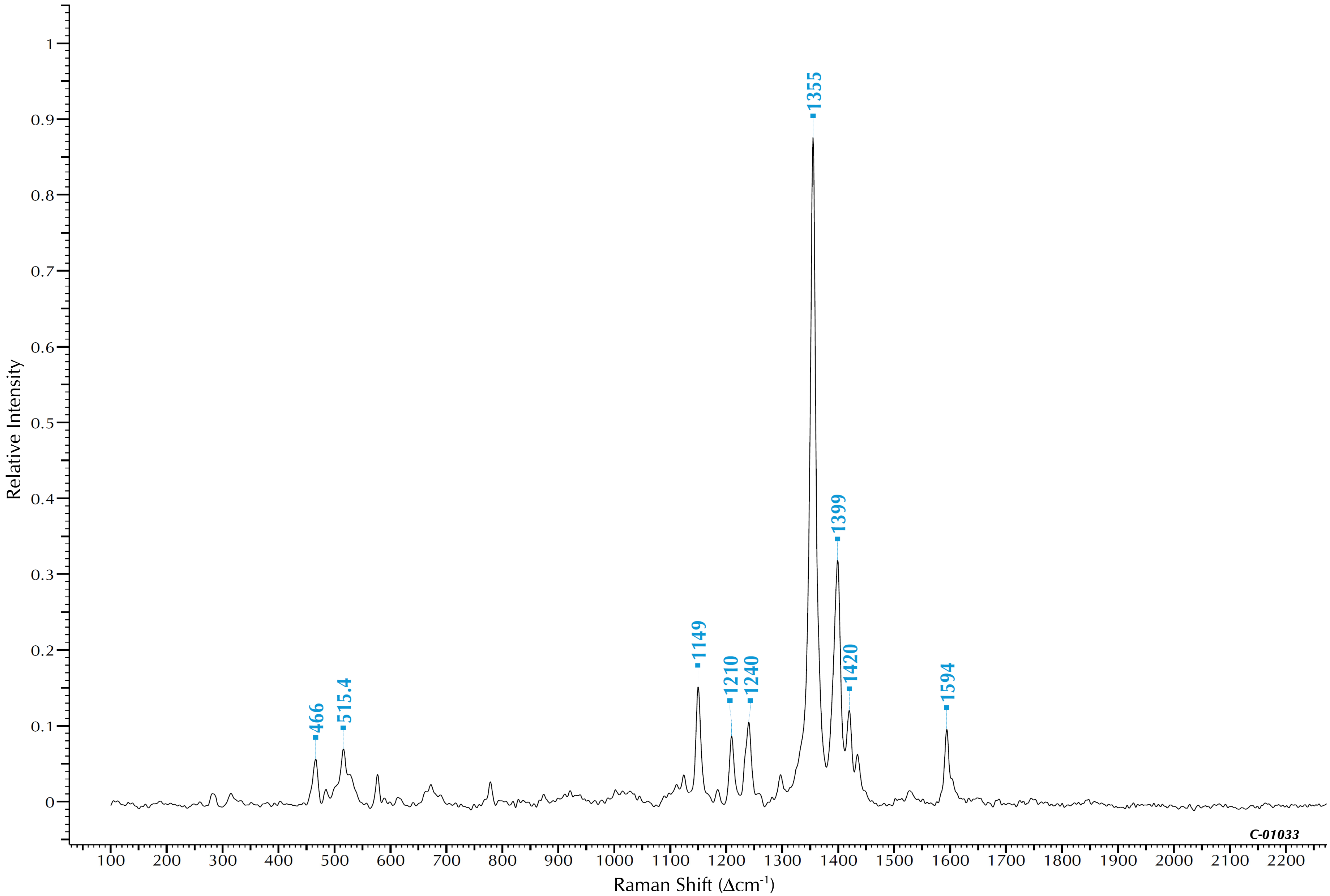
Chemical Category: Organic - Polycyclic - Perylene
Constitution Number: 71129

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.00143
Quality Index 2

Microtrace LLC

C.I. Pigment Violet 37



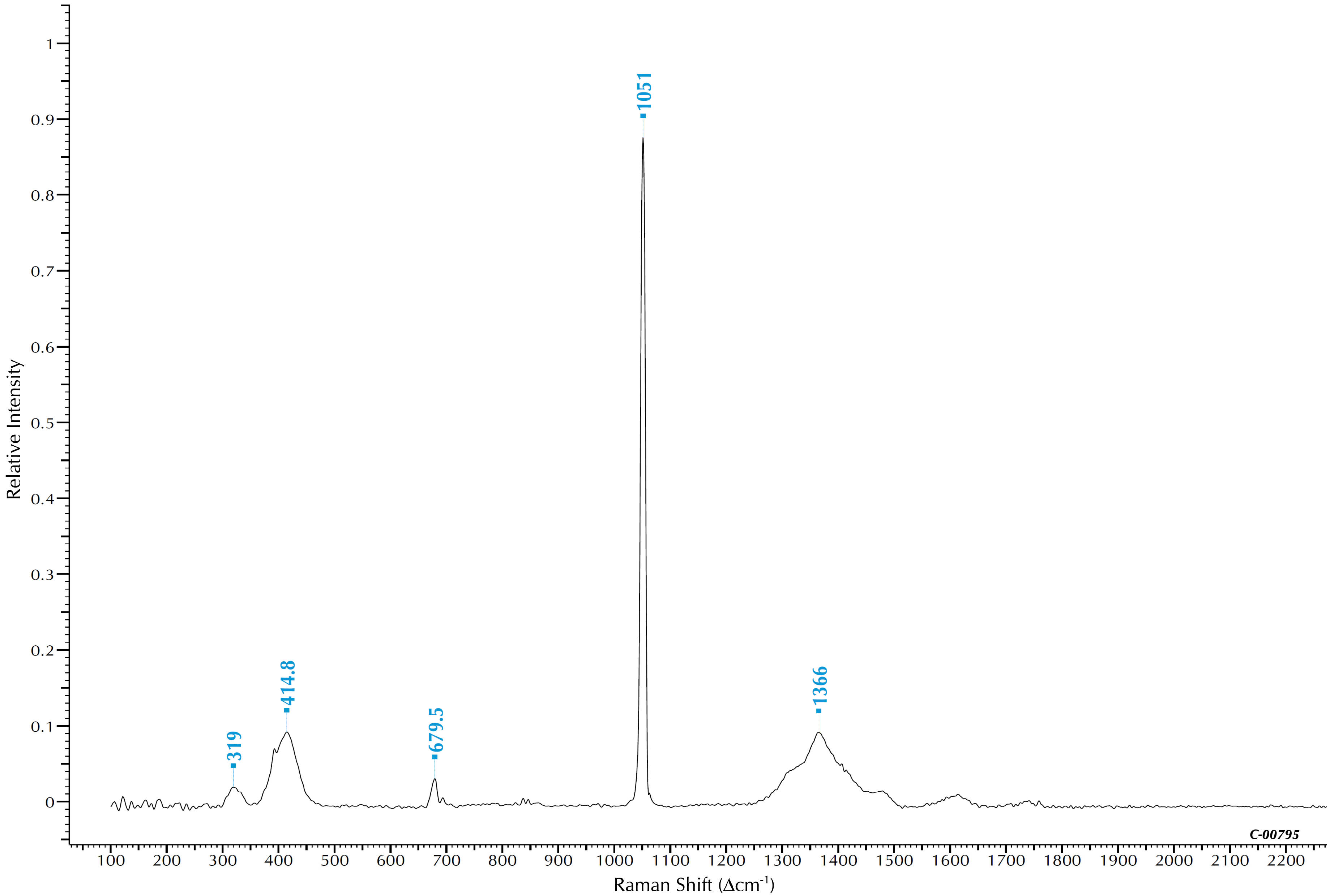
Chemical Category: Organic - Polycyclic - Dioxazine
Constitution Number: 51345

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment White 1



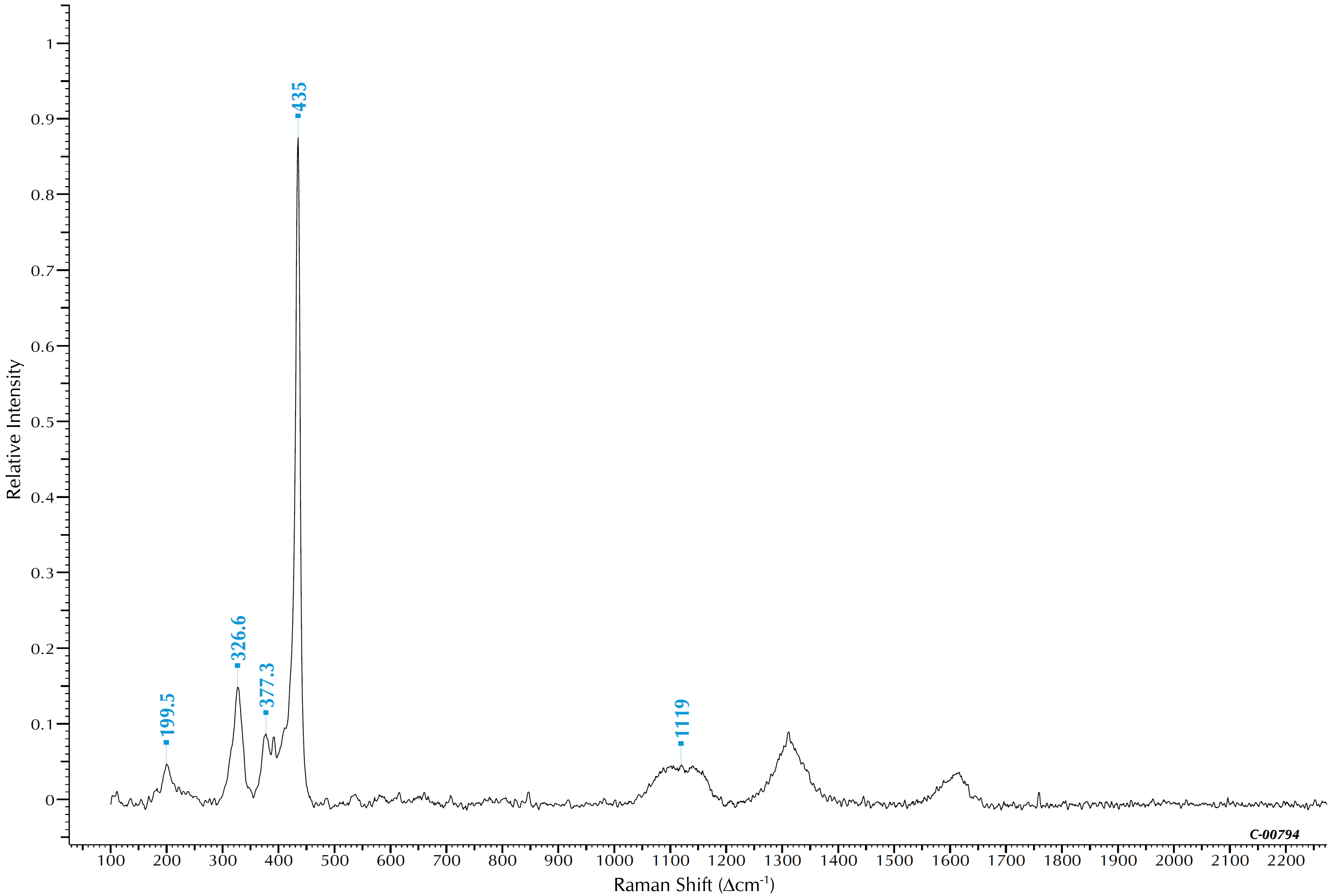
Chemical Category: Inorganic - Carbonate
Constitution Number: 77597

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment White 4



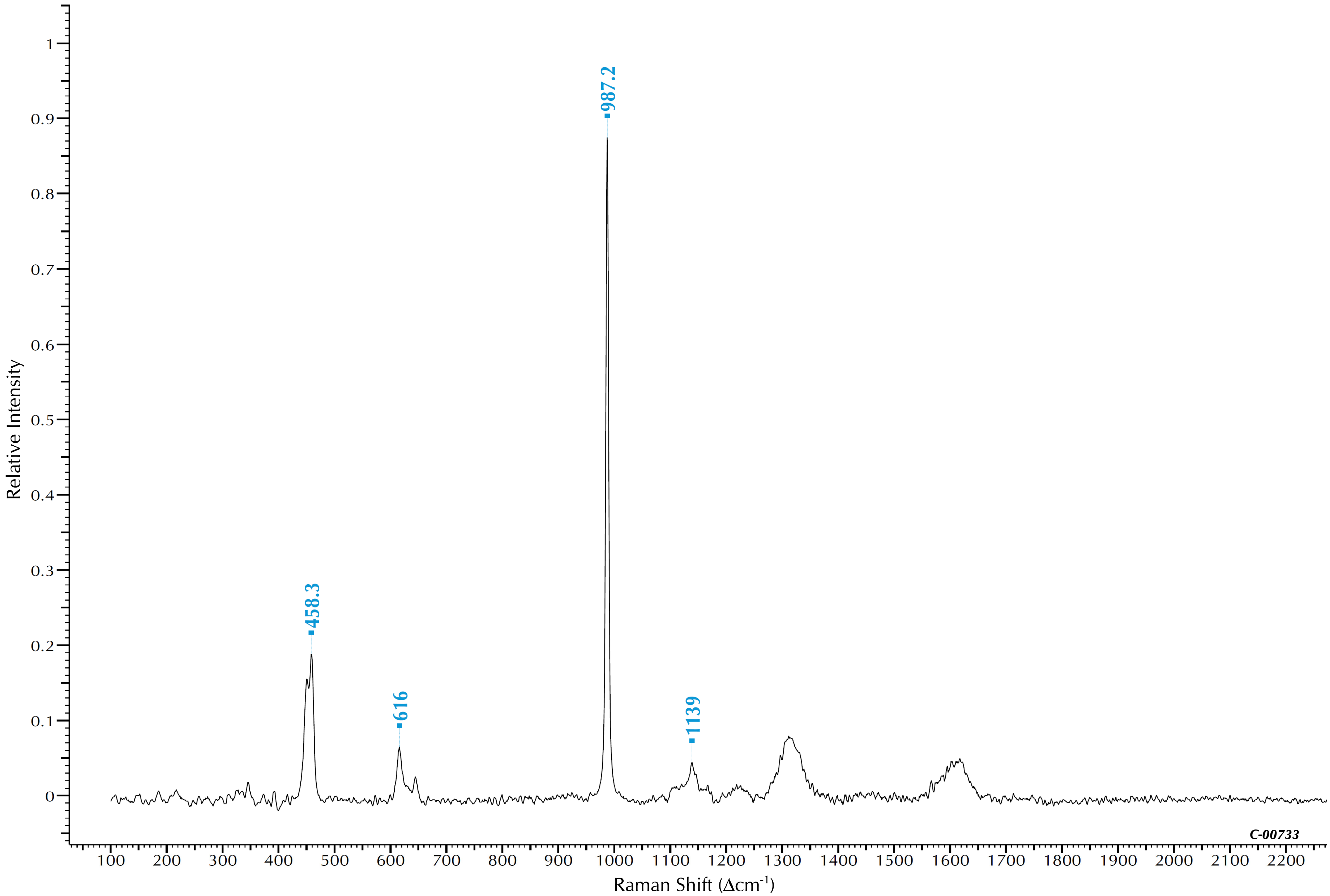
Chemical Category: Inorganic - Oxide
Constitution Number: 77947

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 3

Microtrace LLC

C.I. Pigment White 5



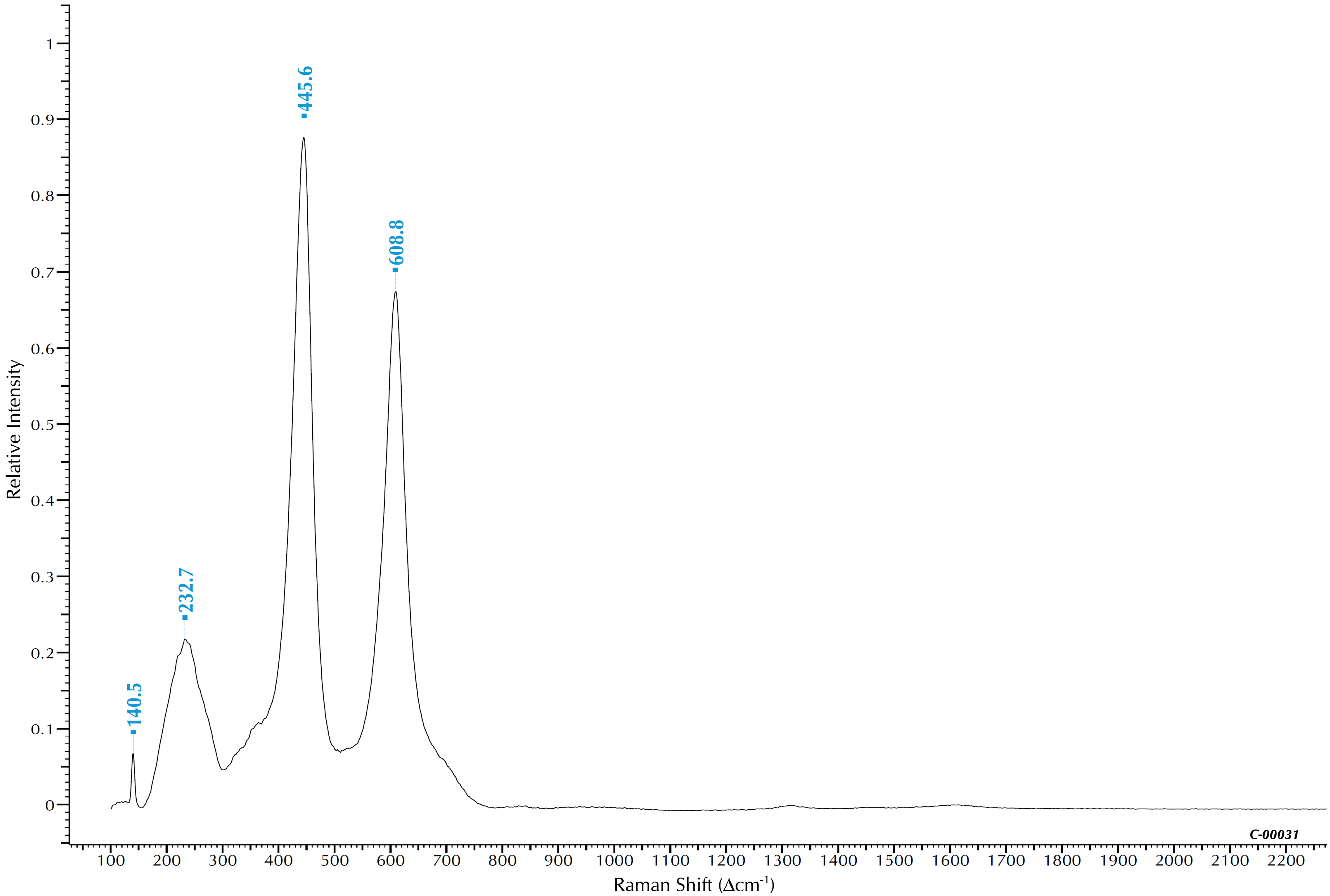
Chemical Category: Inorganic - Sulfate
Constitution Number: 77115

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 4

Microtrace LLC

C.I. Pigment White 6 (Rutile)



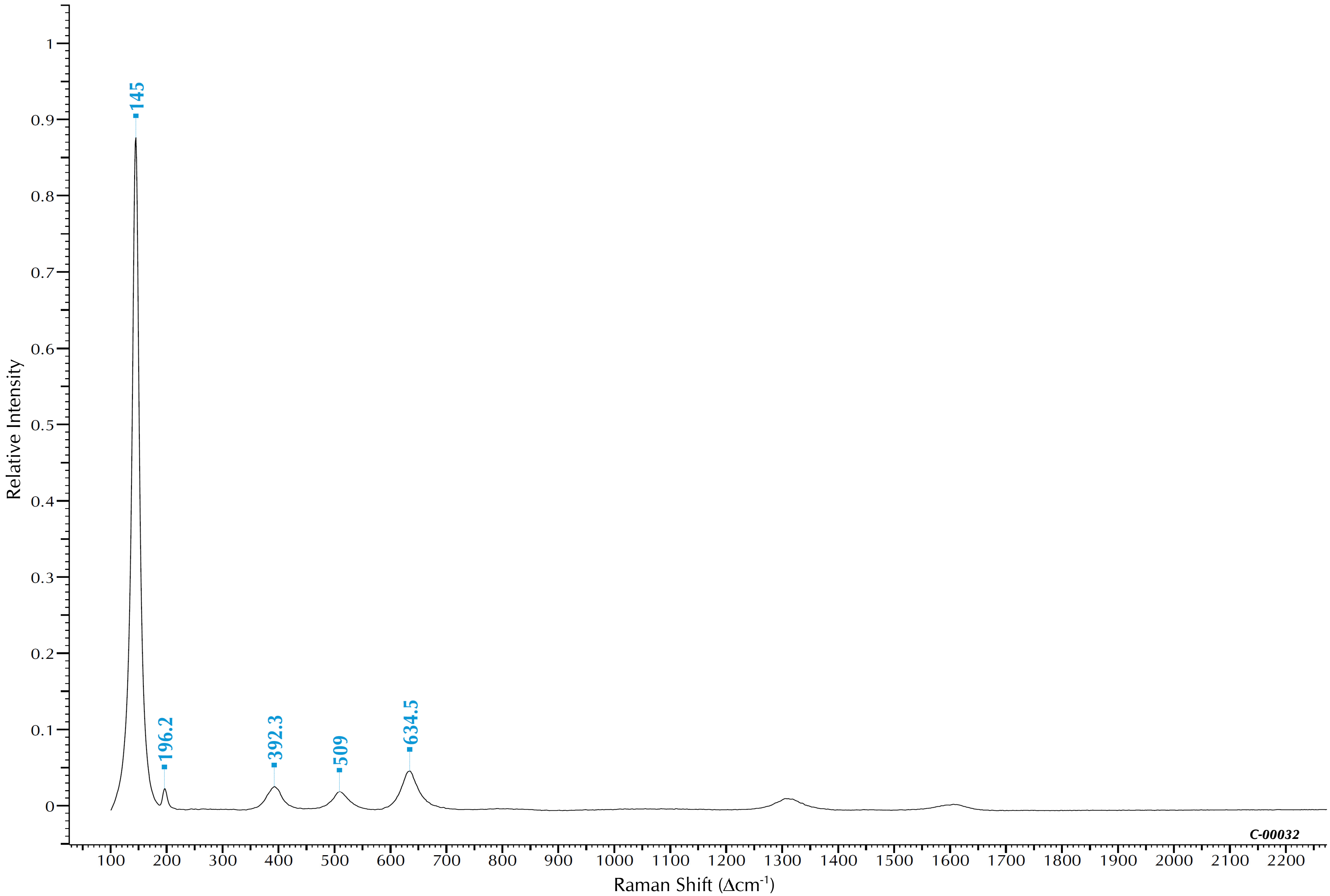
Chemical Category: Inorganic - Titanate
Constitution Number: 77891 77019

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment White 6 (Anatase)



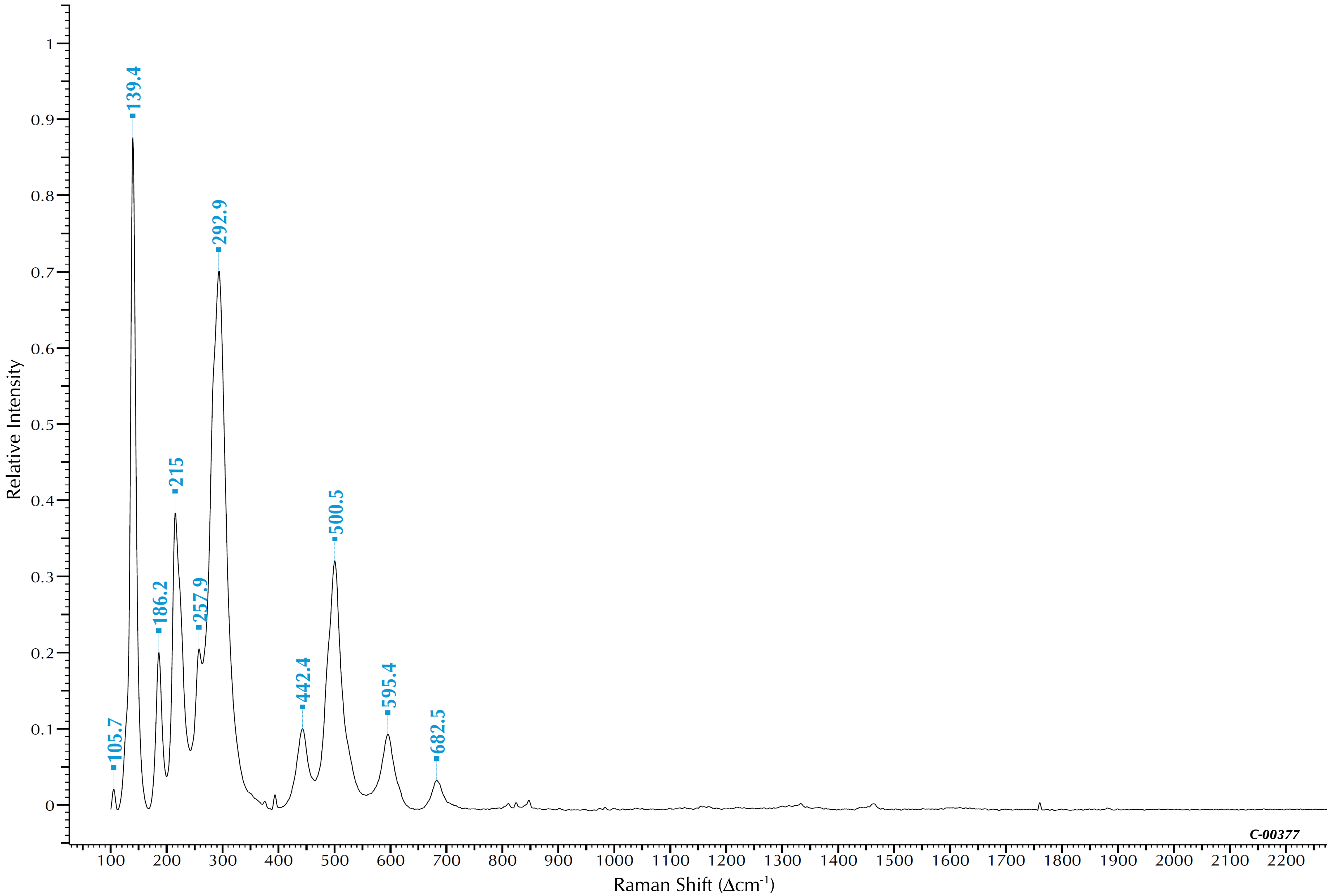
Chemical Category: Inorganic - Titanate
Constitution Number: 77891 77019

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment White 11



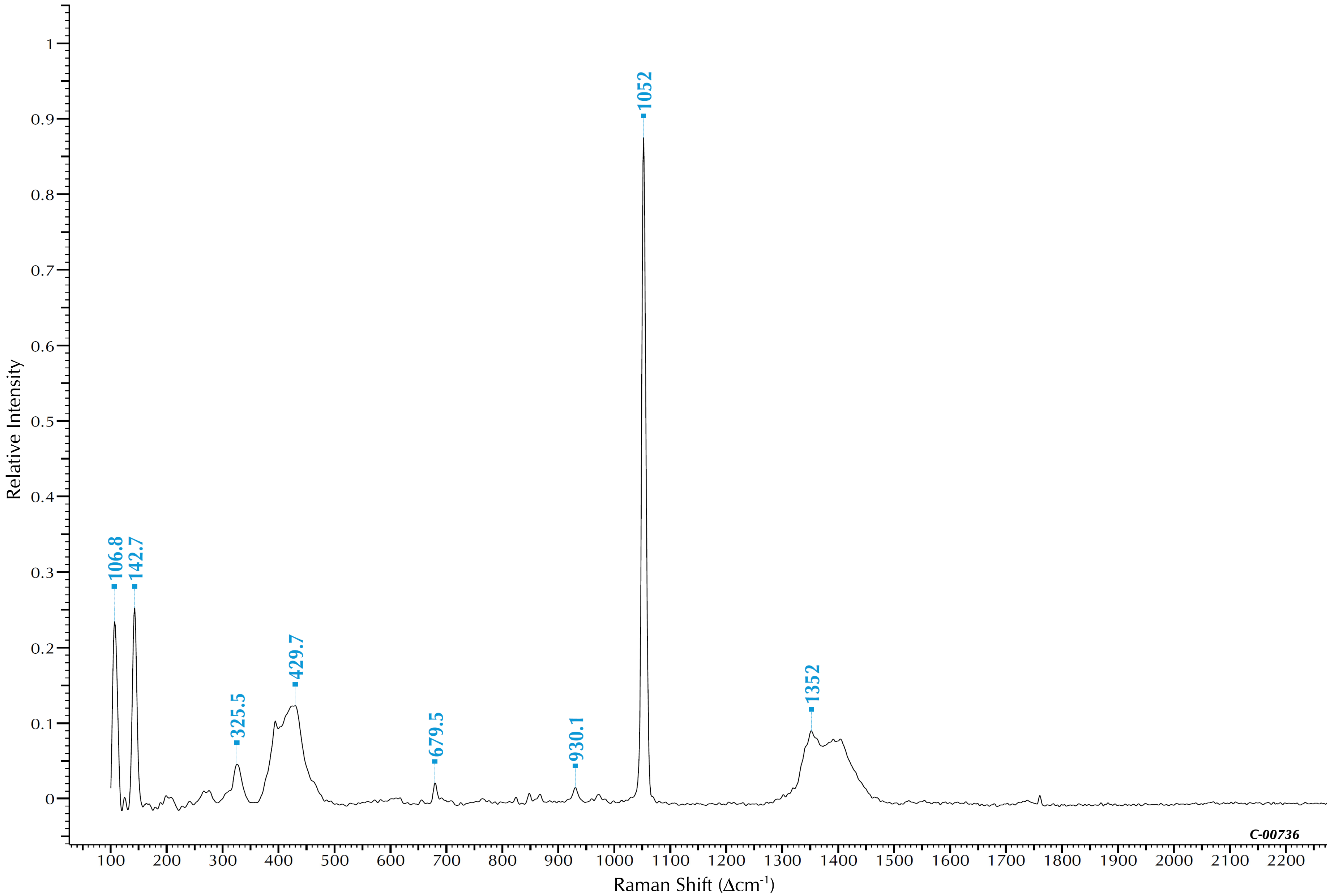
Chemical Category: Inorganic - Oxide
Constitution Number: 77052

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 5

Microtrace LLC

C.I. Pigment White 16

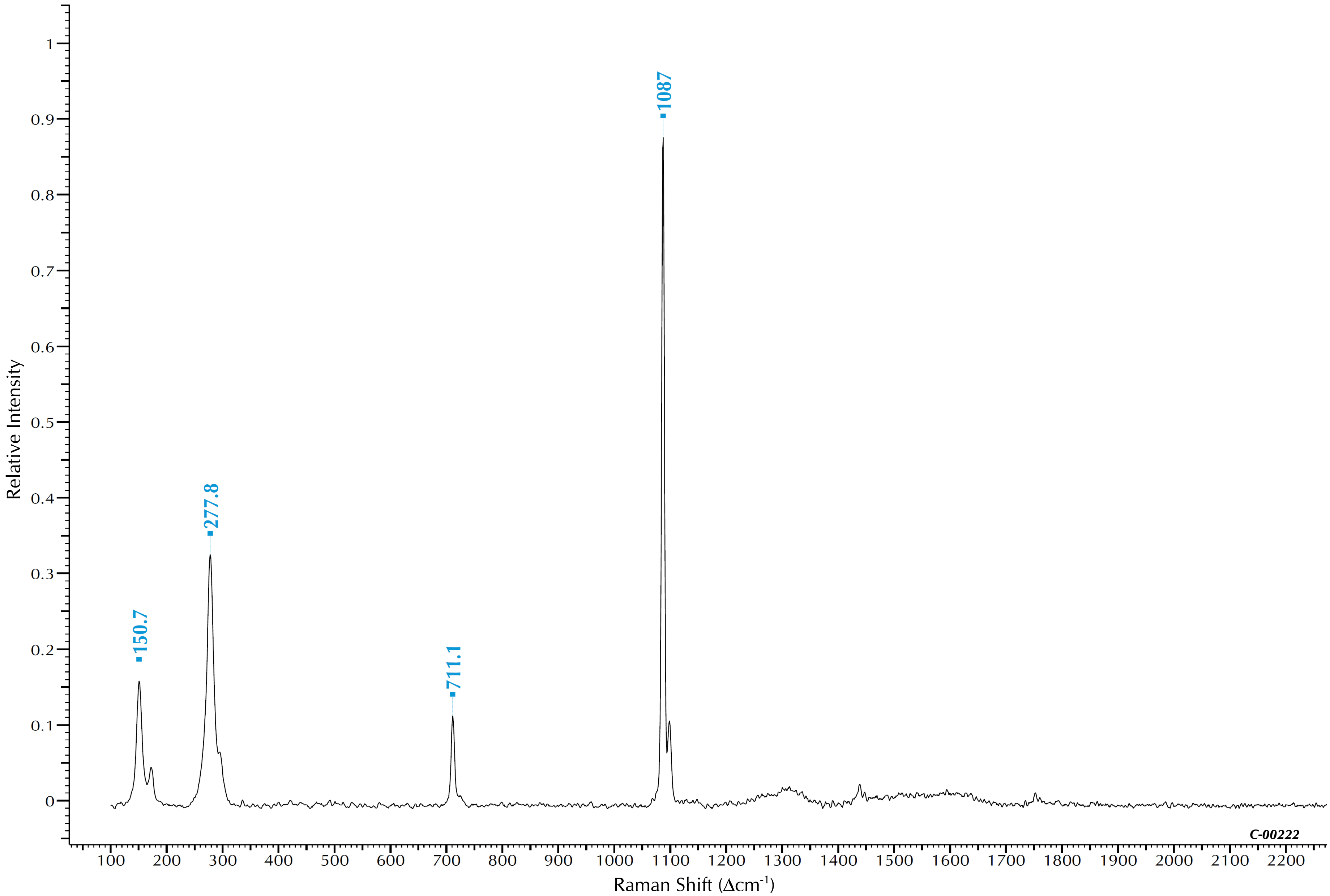


Chemical Category: Inorganic - Carbonate
Constitution Number: 77625

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 4

C.I. Pigment White 18



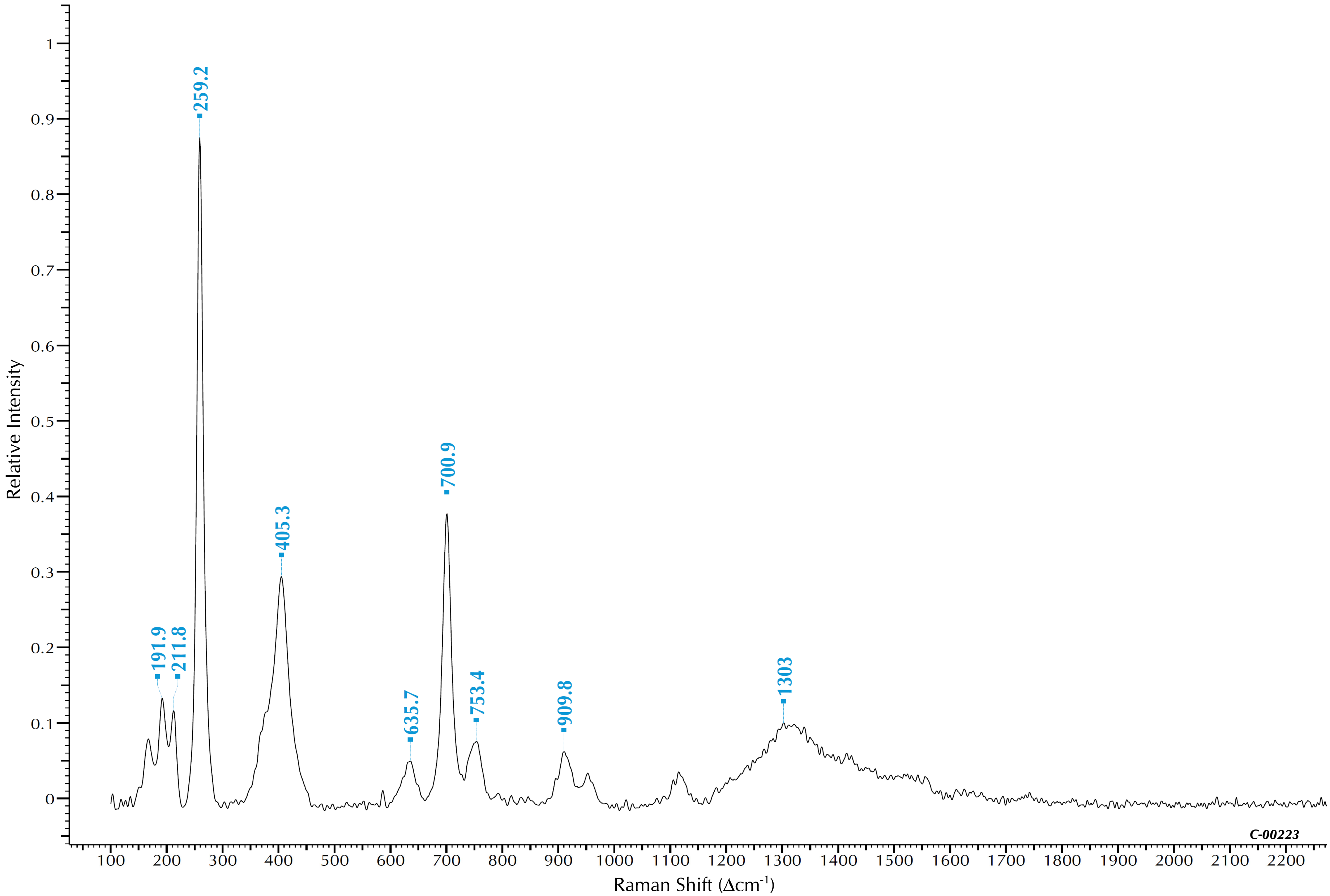
Chemical Category: Inorganic - Carbonate
Constitution Number: 77220 77713

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment White 20



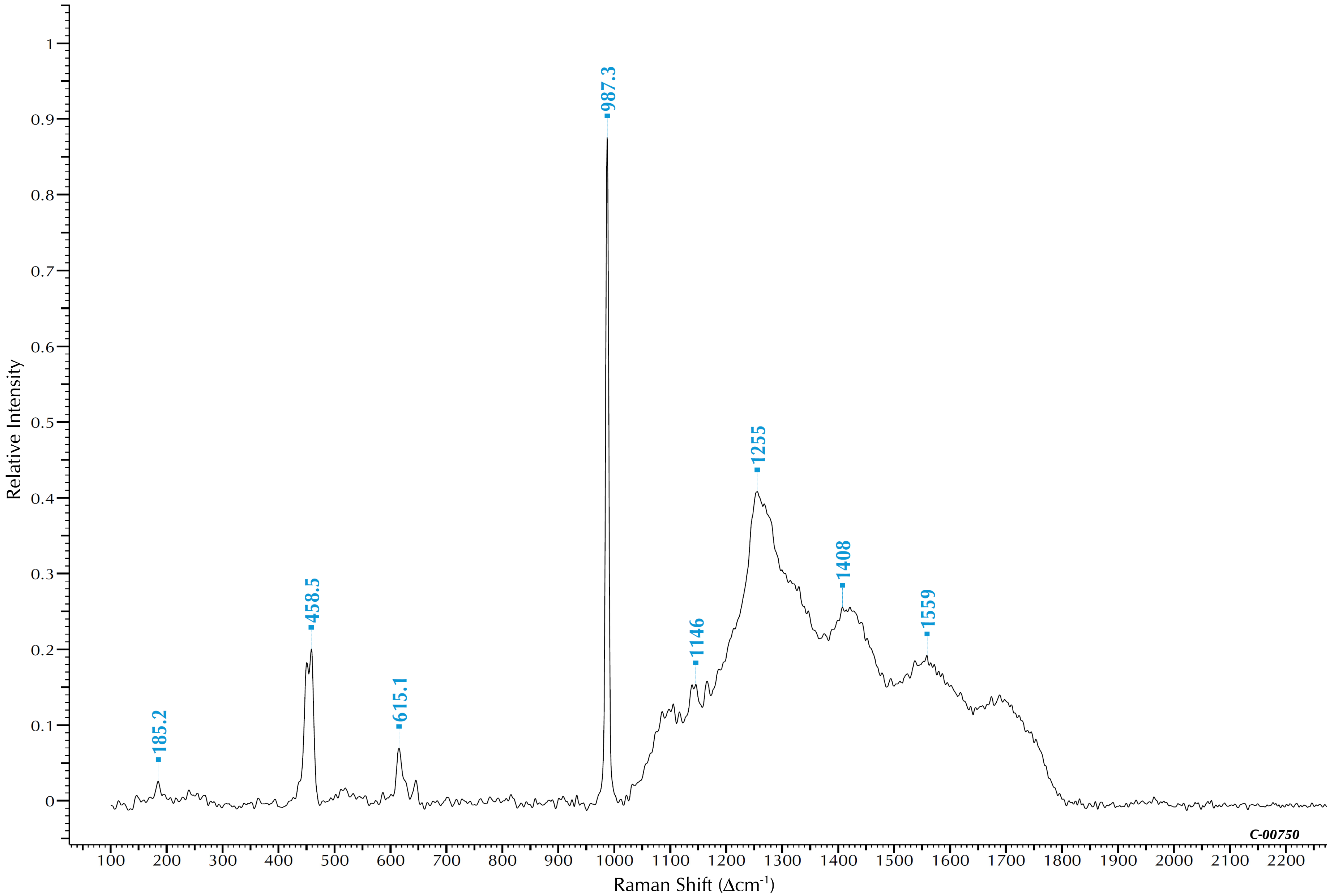
Chemical Category: Inorganic - Silicate
Constitution Number: 77019

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 5

Laser λ (nm) 785
Power (mW) 19.3
Quality Index 3

Microtrace LLC

C.I. Pigment White 21



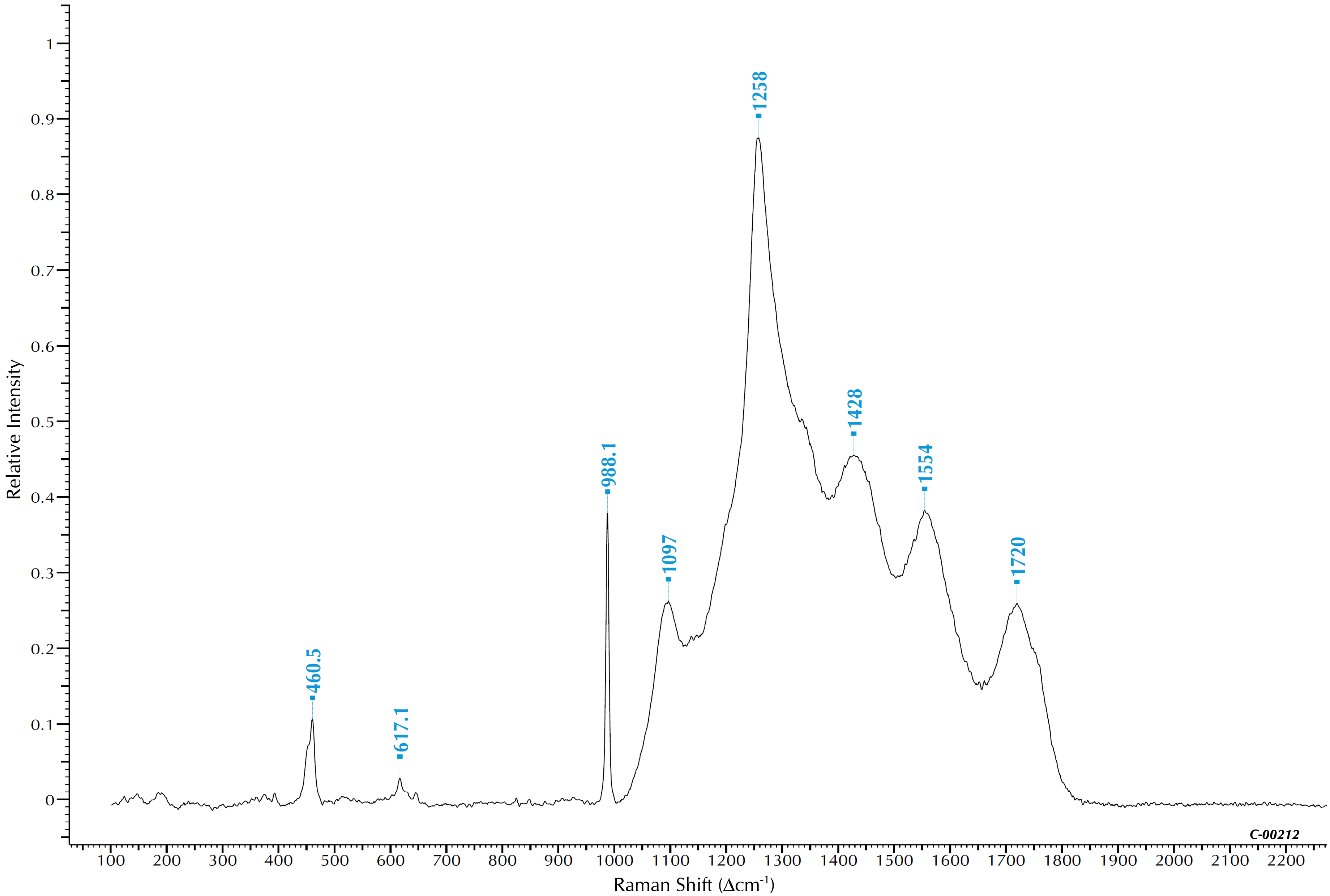
Chemical Category: Inorganic - Sulfate
Constitution Number: 77120

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment White 22



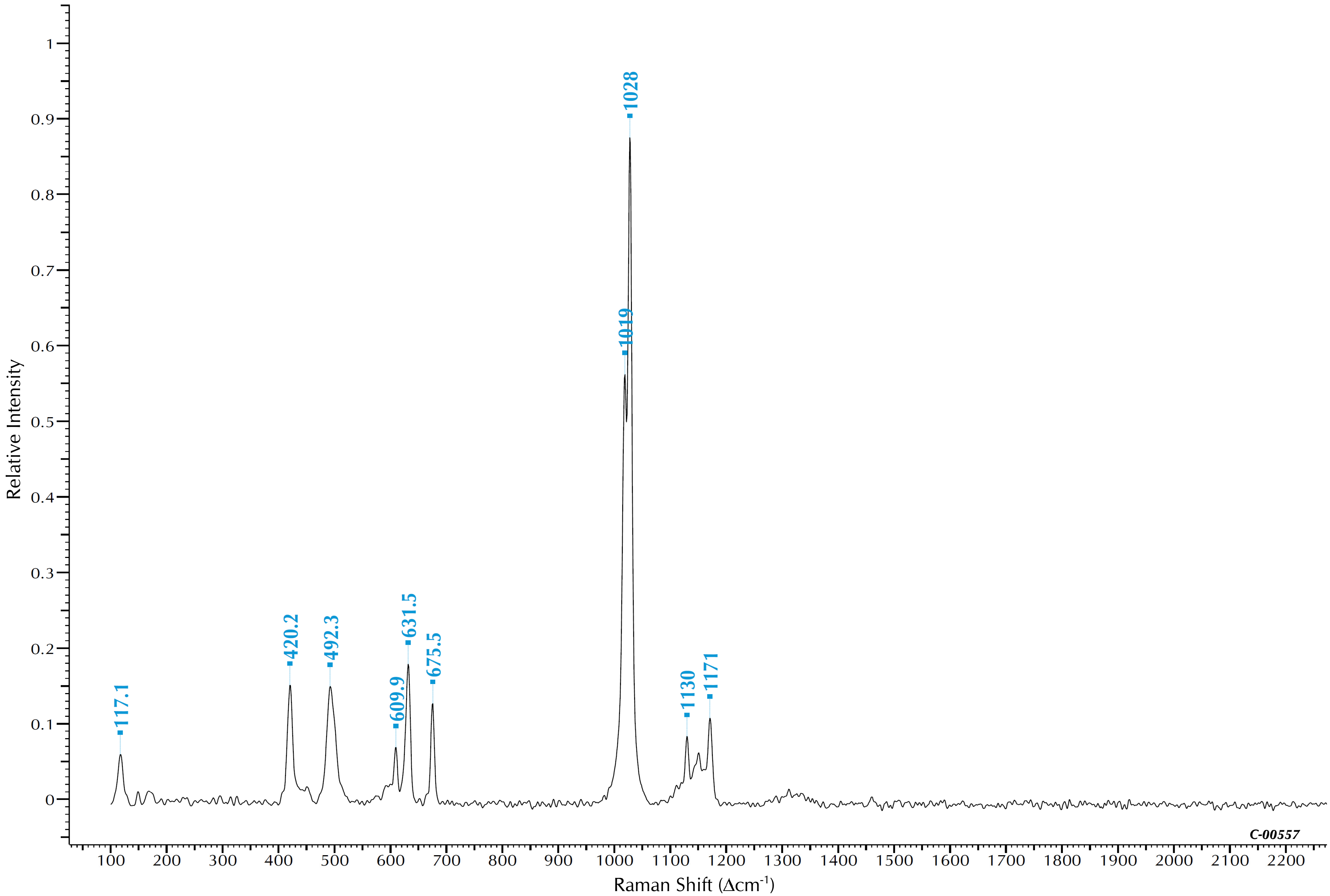
Chemical Category: Inorganic - Sulfate
Constitution Number: 77120

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment White 25



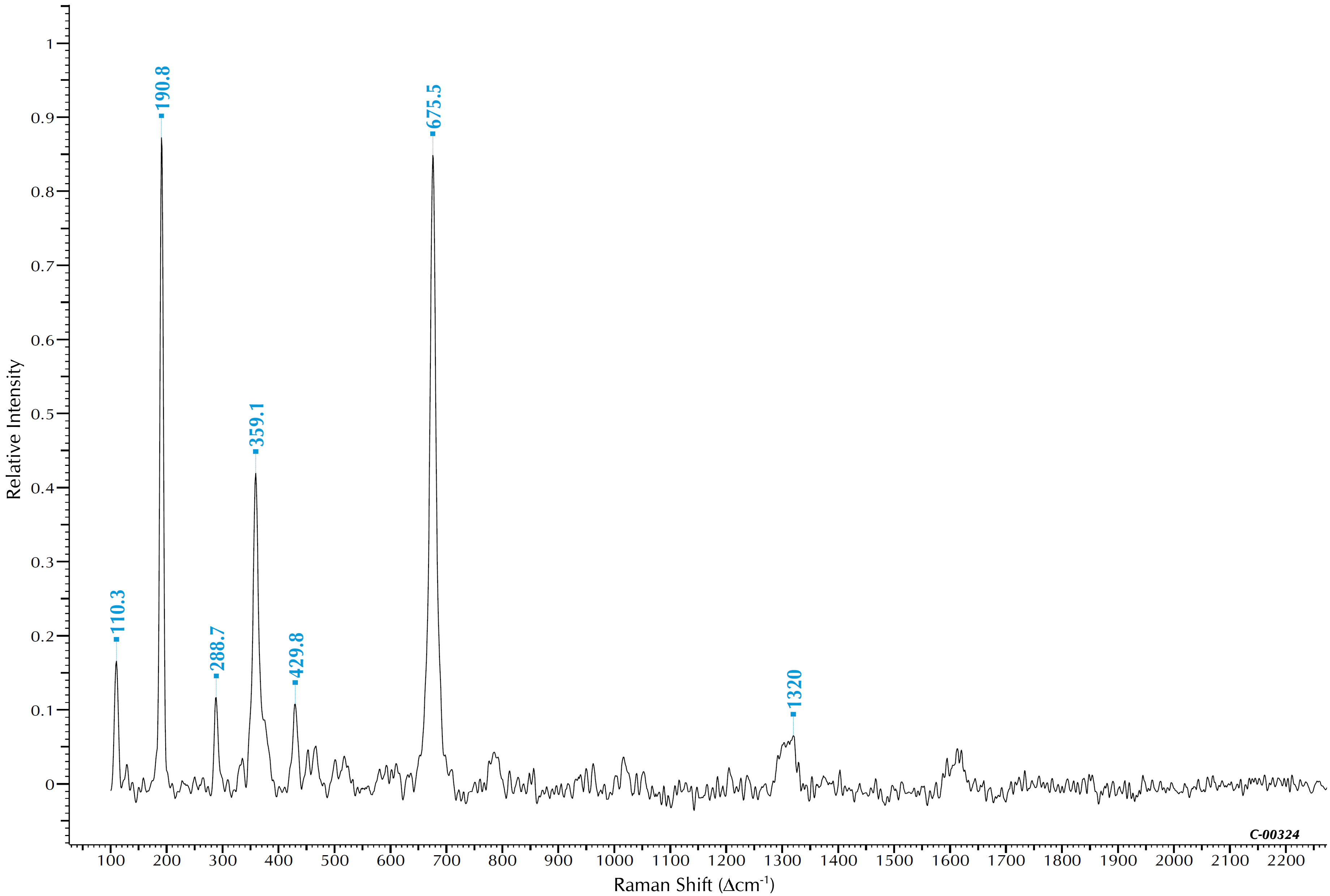
Chemical Category: Inorganic - Sulfate
Constitution Number: 77231

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 5

Microtrace LLC

C.I. Pigment White 26



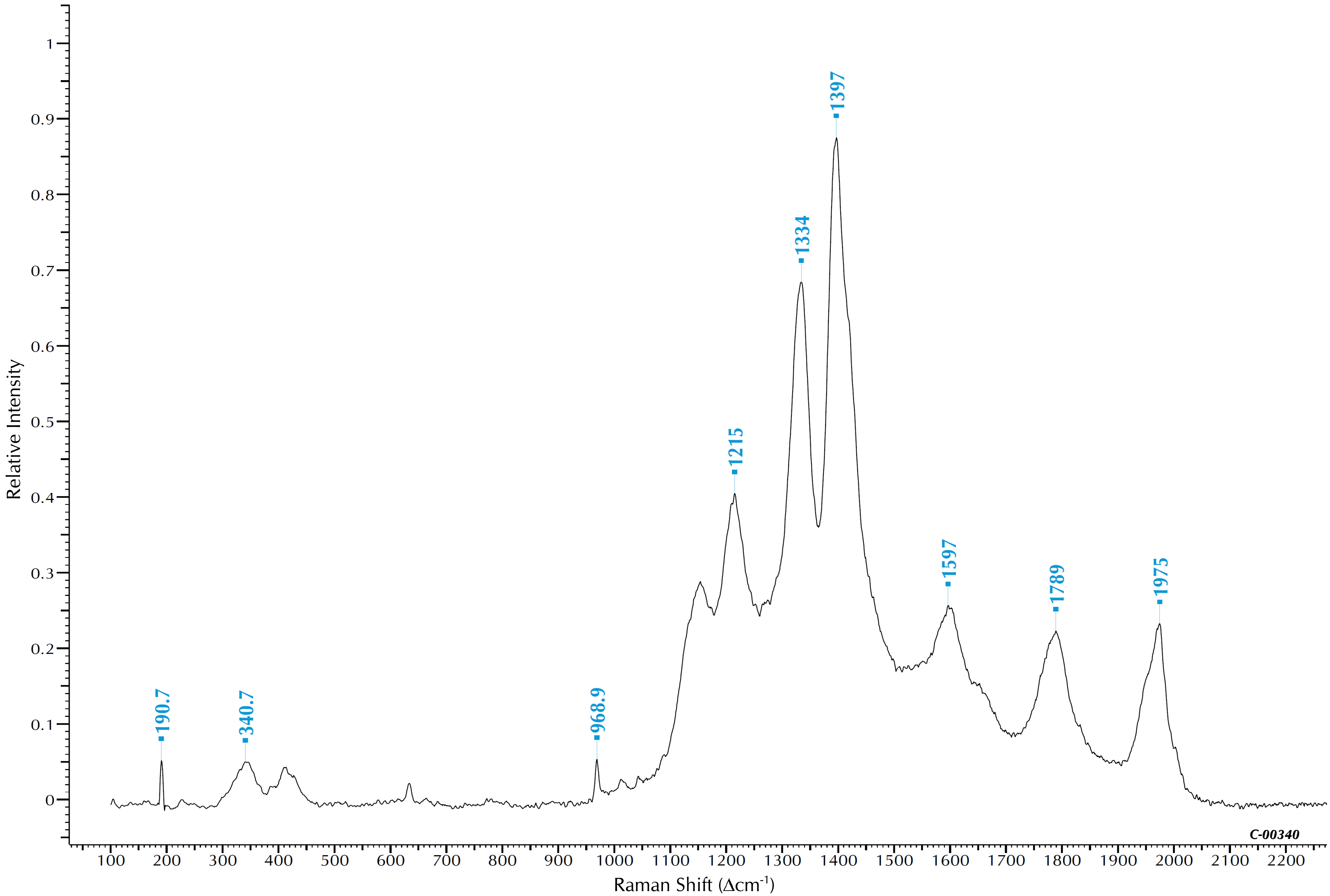
Chemical Category: Inorganic - Hydroxide
Constitution Number: 77718 77019

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 1

Microtrace LLC

C.I. Pigment White 28



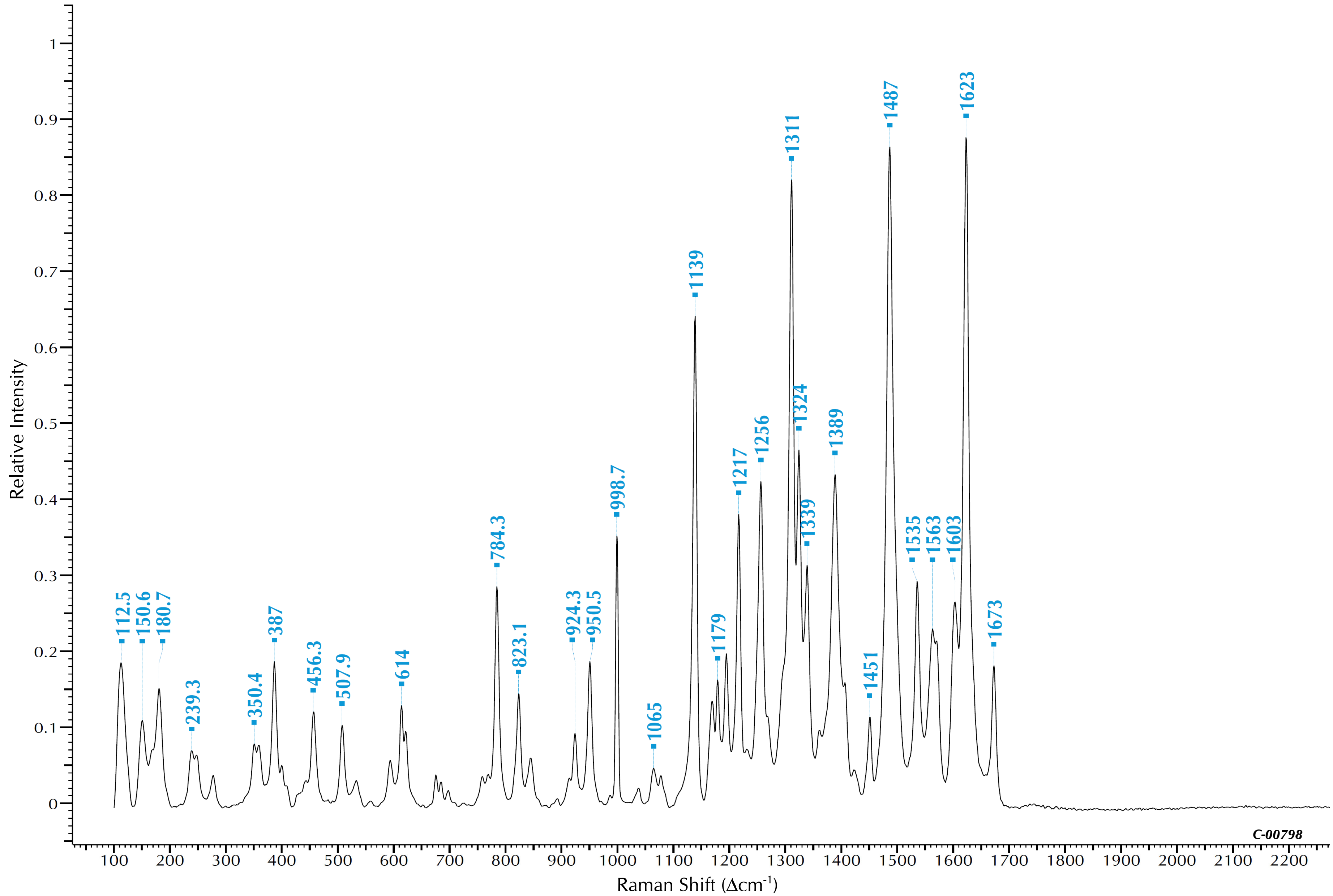
Chemical Category: Inorganic - Silicate
Constitution Number: 77230

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 1



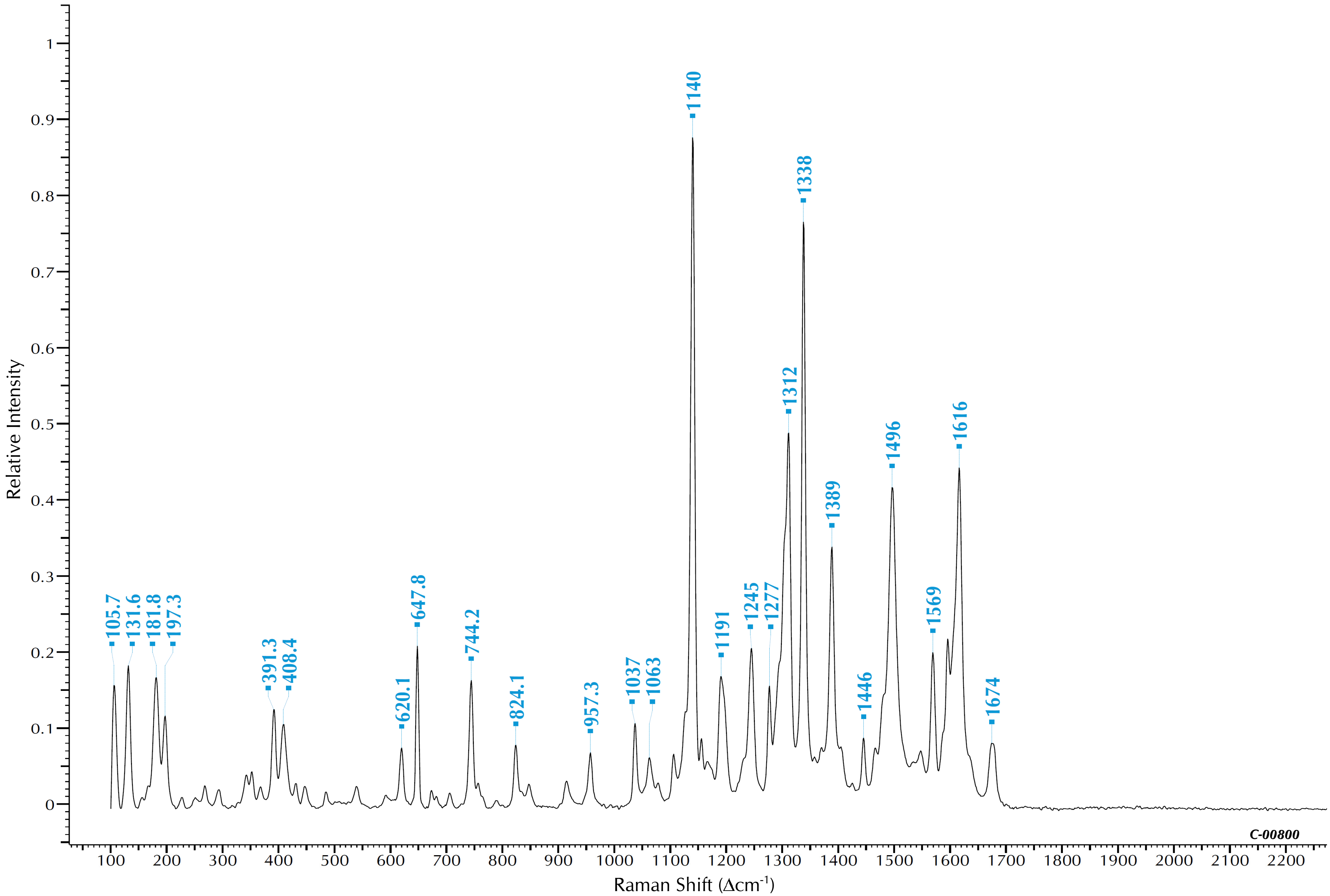
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11680

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 3



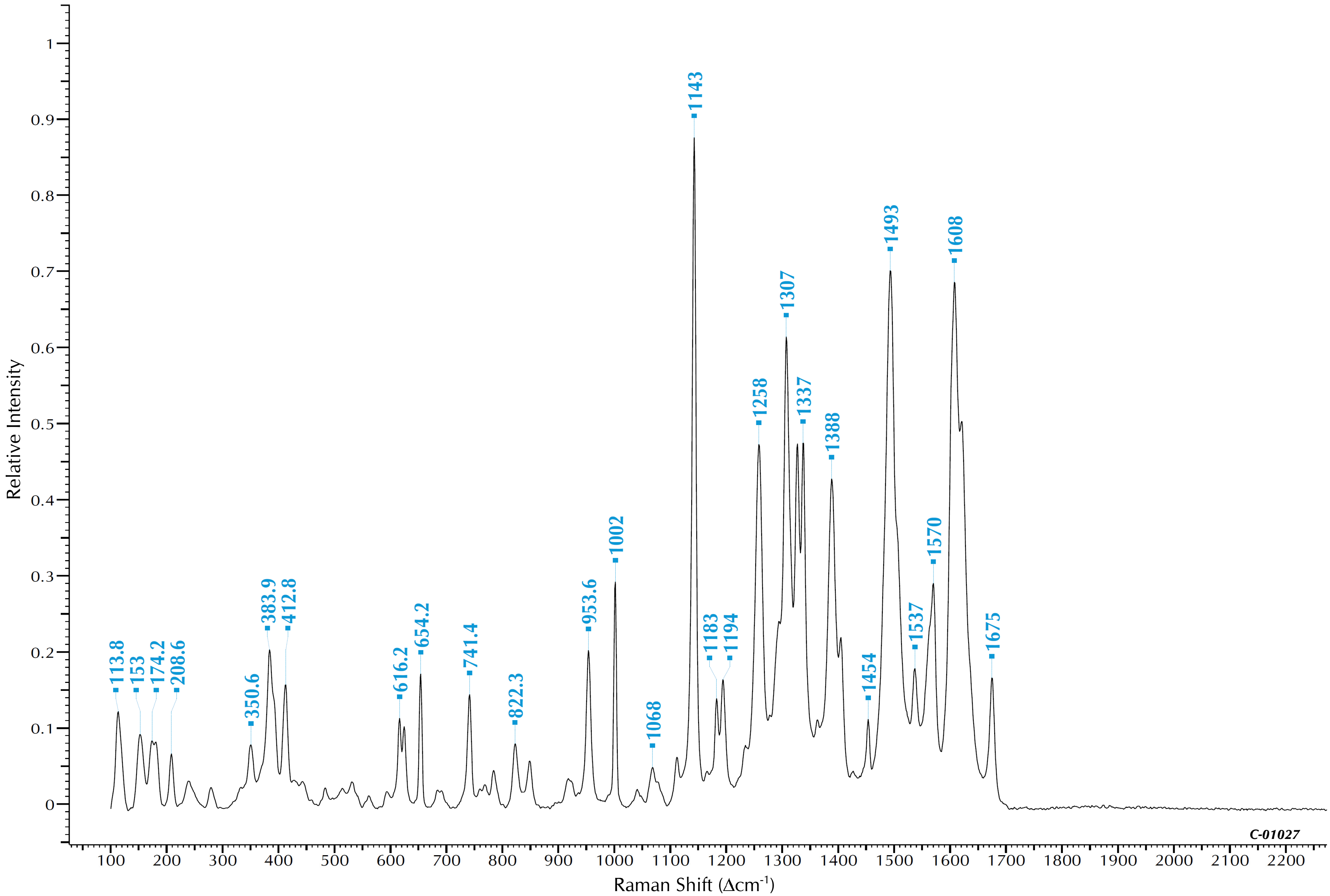
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11710

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 6



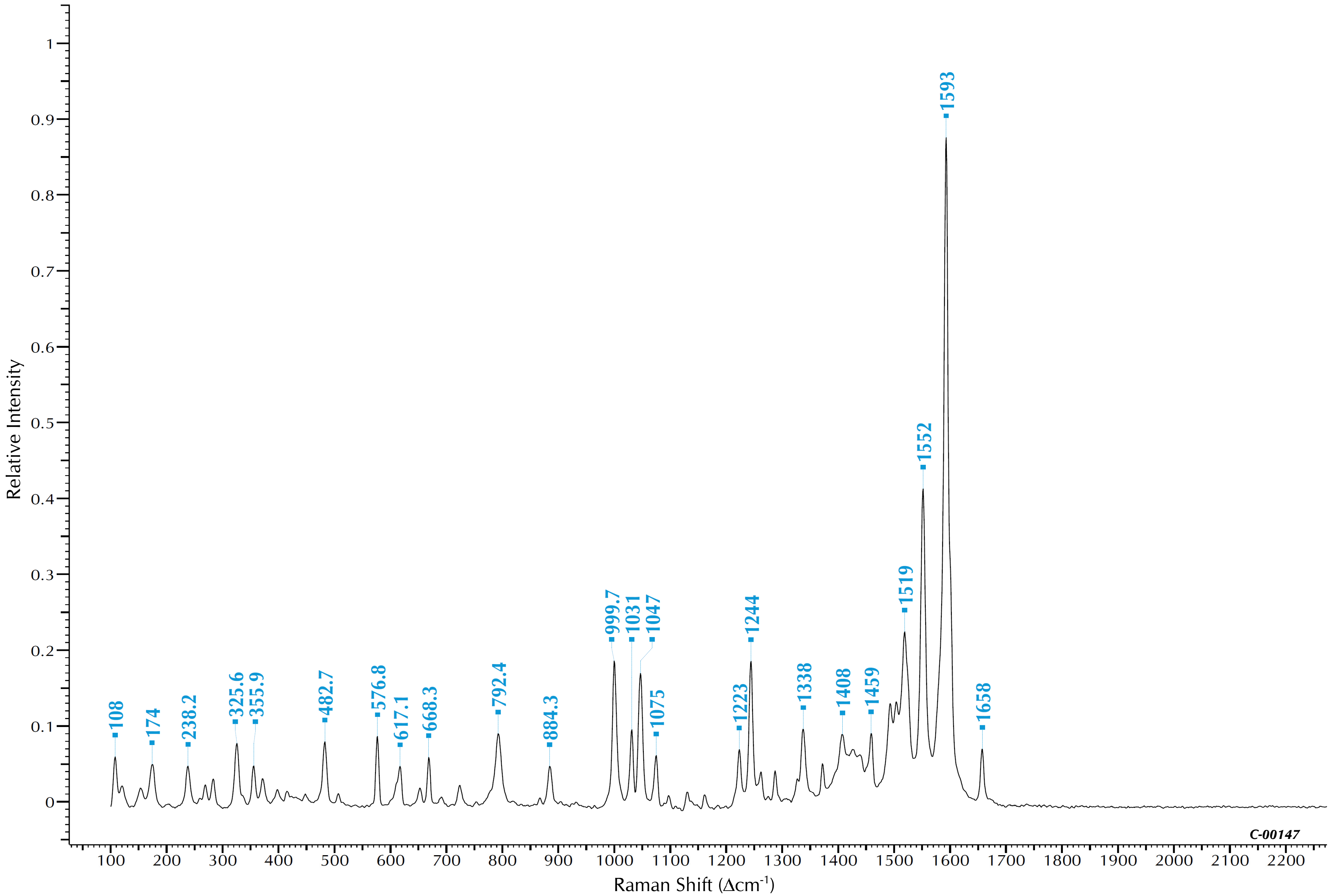
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11670

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 10



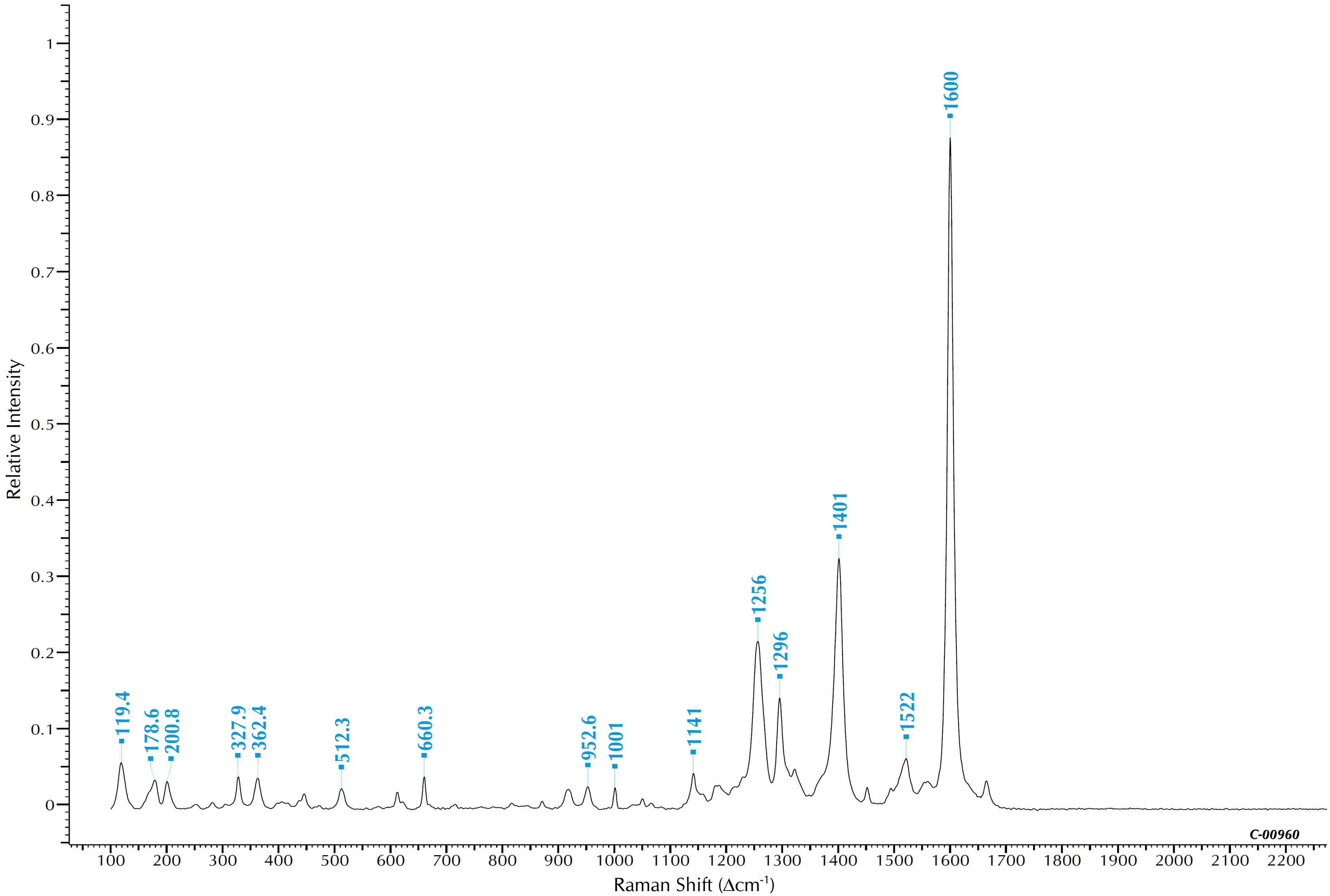
Chemical Category: Organic - Azo - Monoazo - Deviated
Constitution Number: 12710

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 12



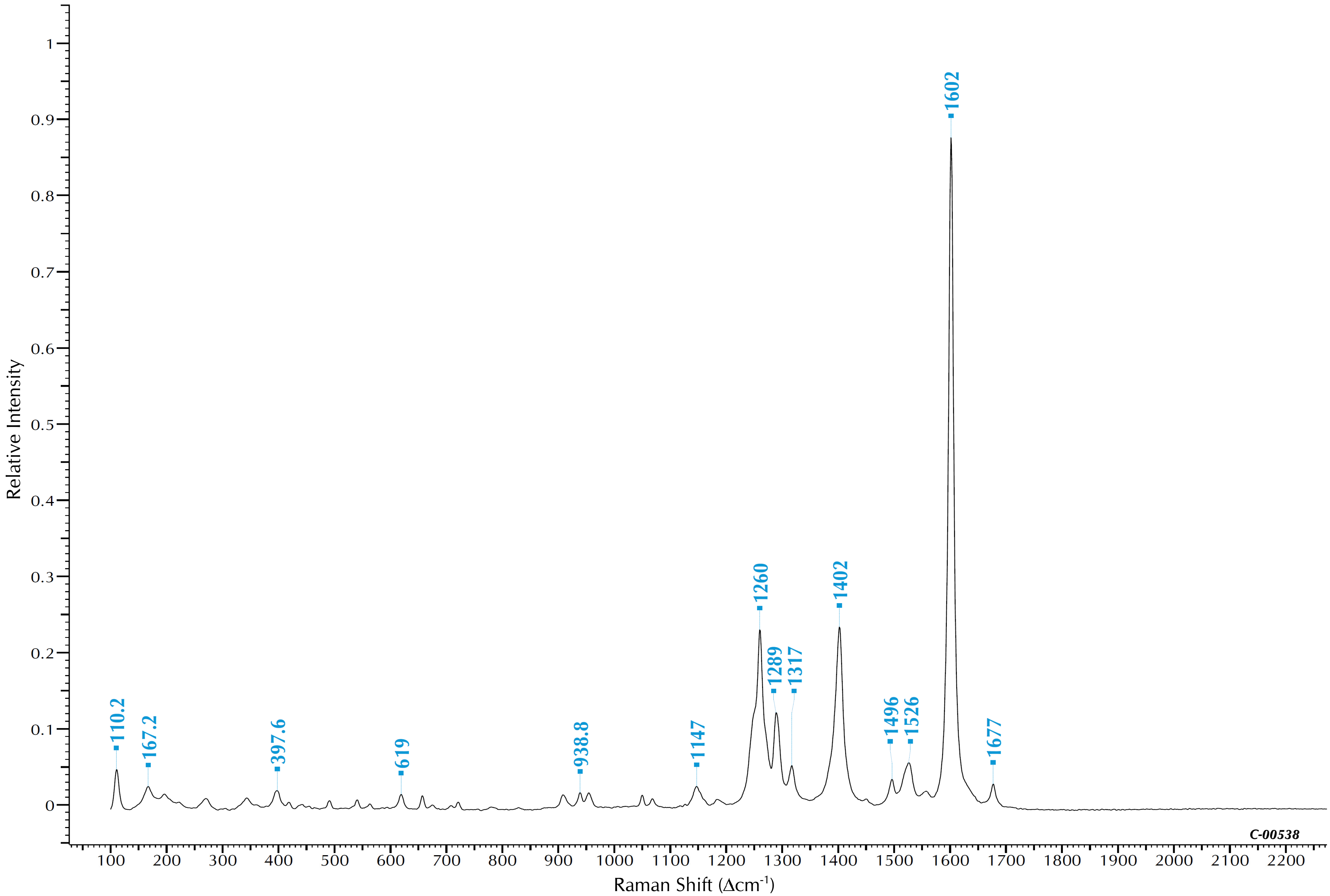
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21090

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 13



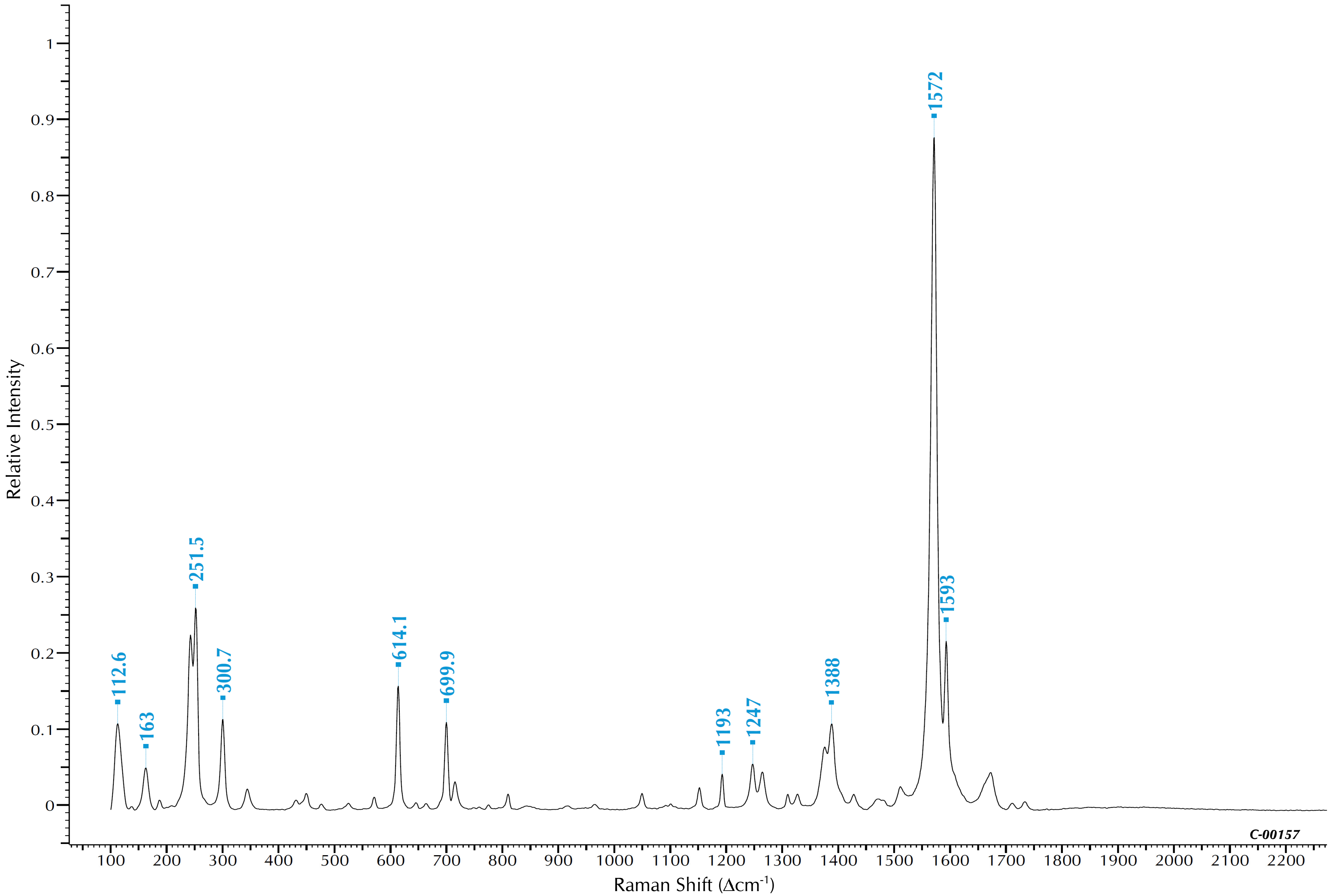
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21100

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 14

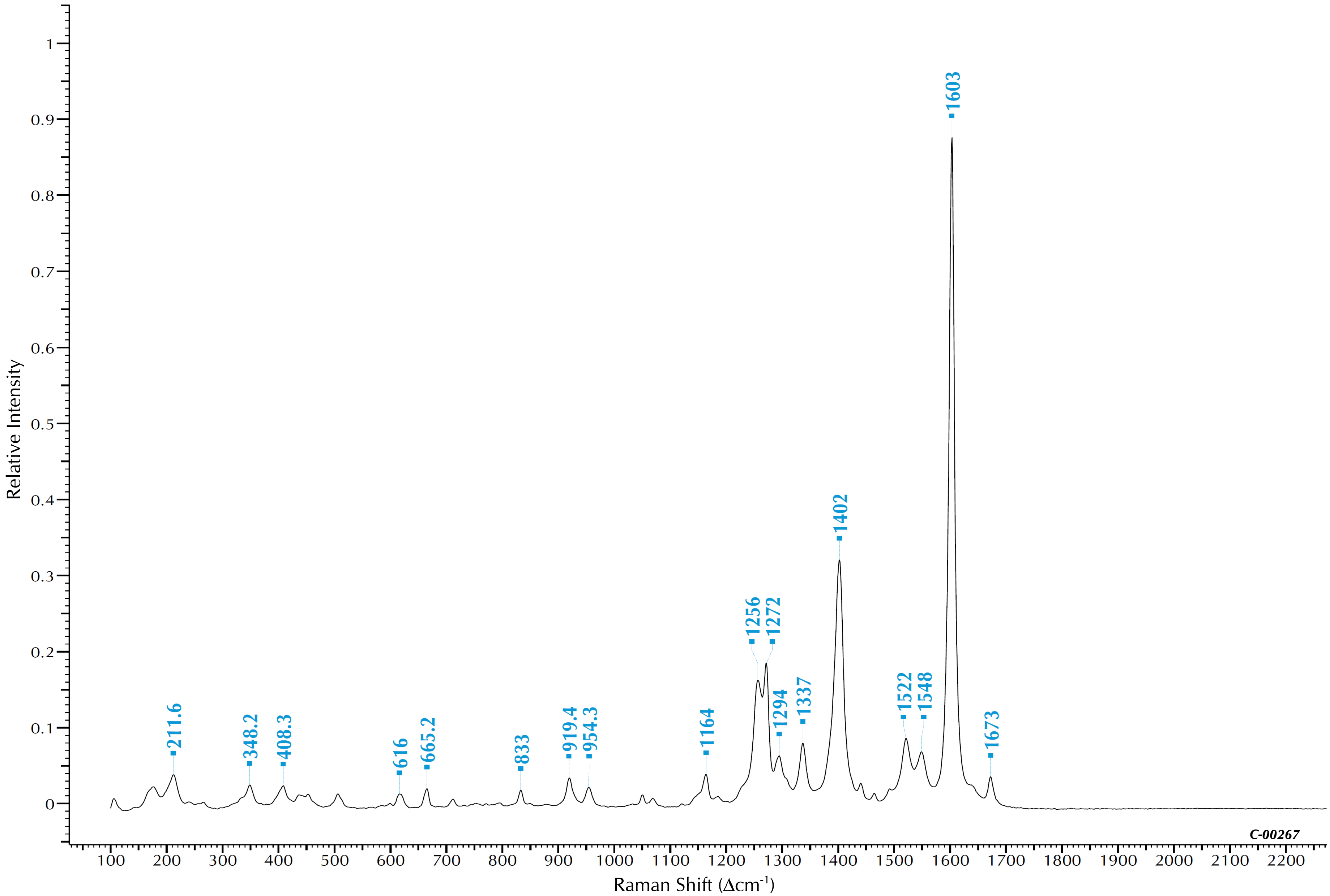


Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21095

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

C.I. Pigment Yellow 17



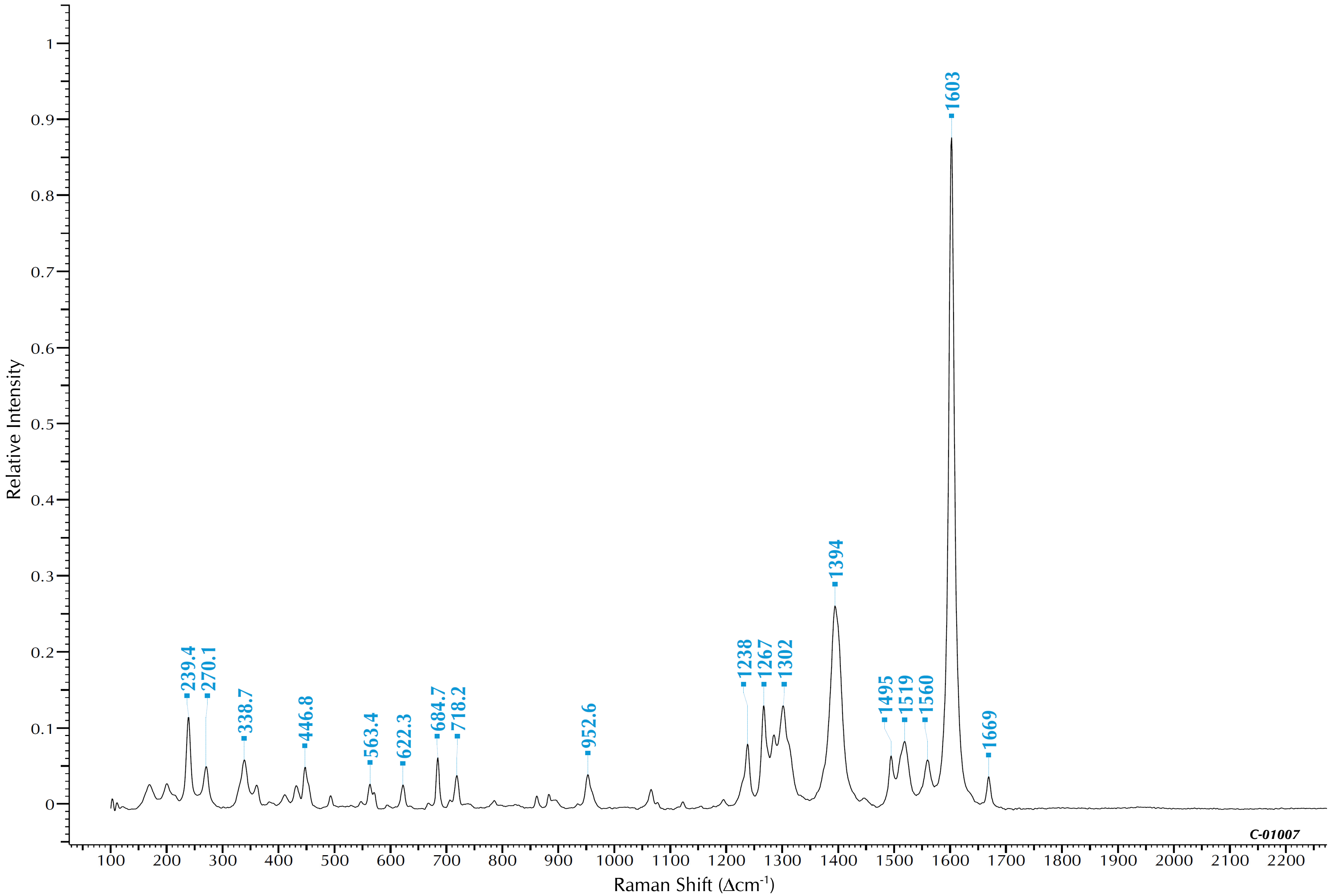
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21105

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 24



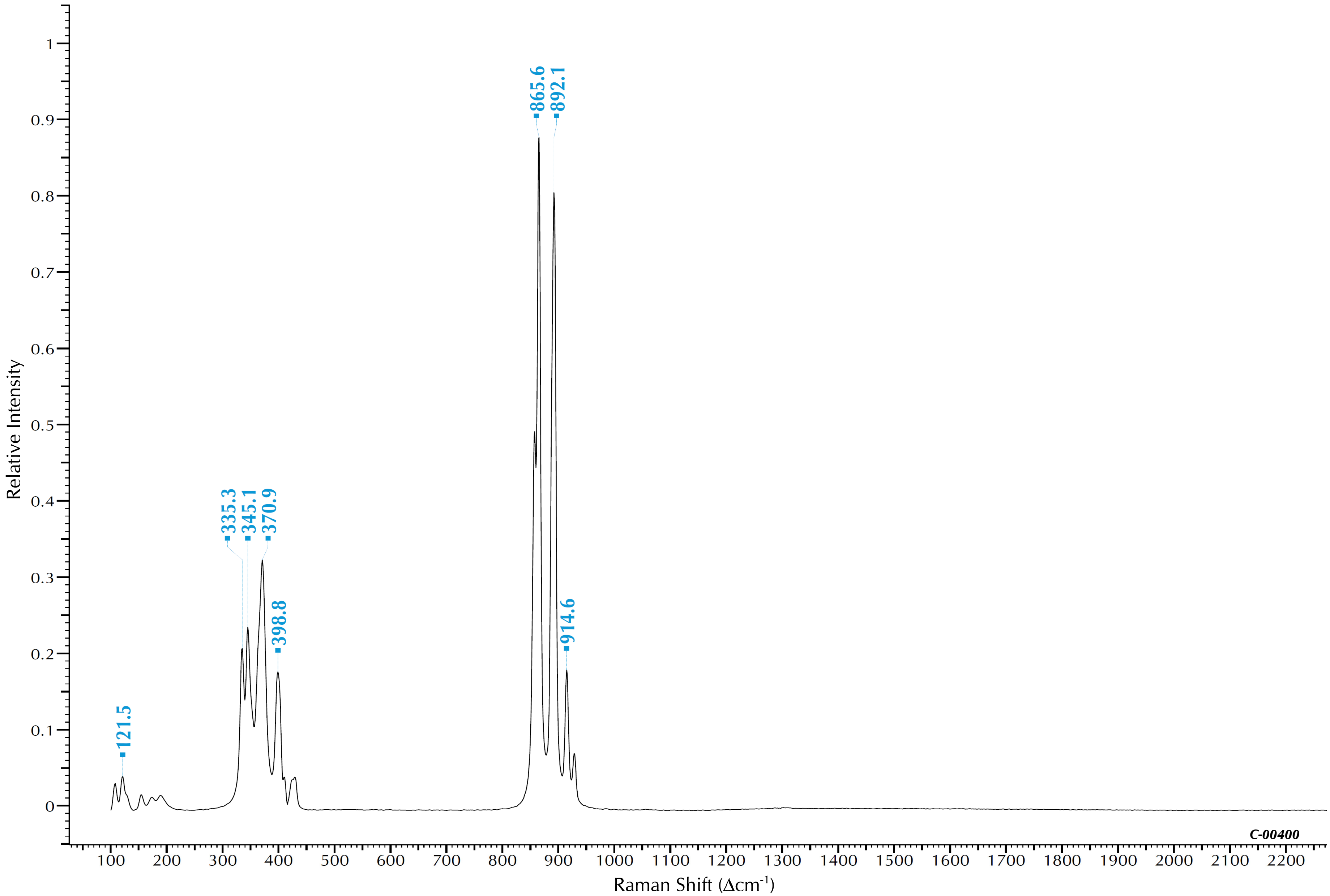
Chemical Category: Organic - Polycyclic - Heterocyclic Anthraquinone - Flavanthrone
Constitution Number: 70600

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 32



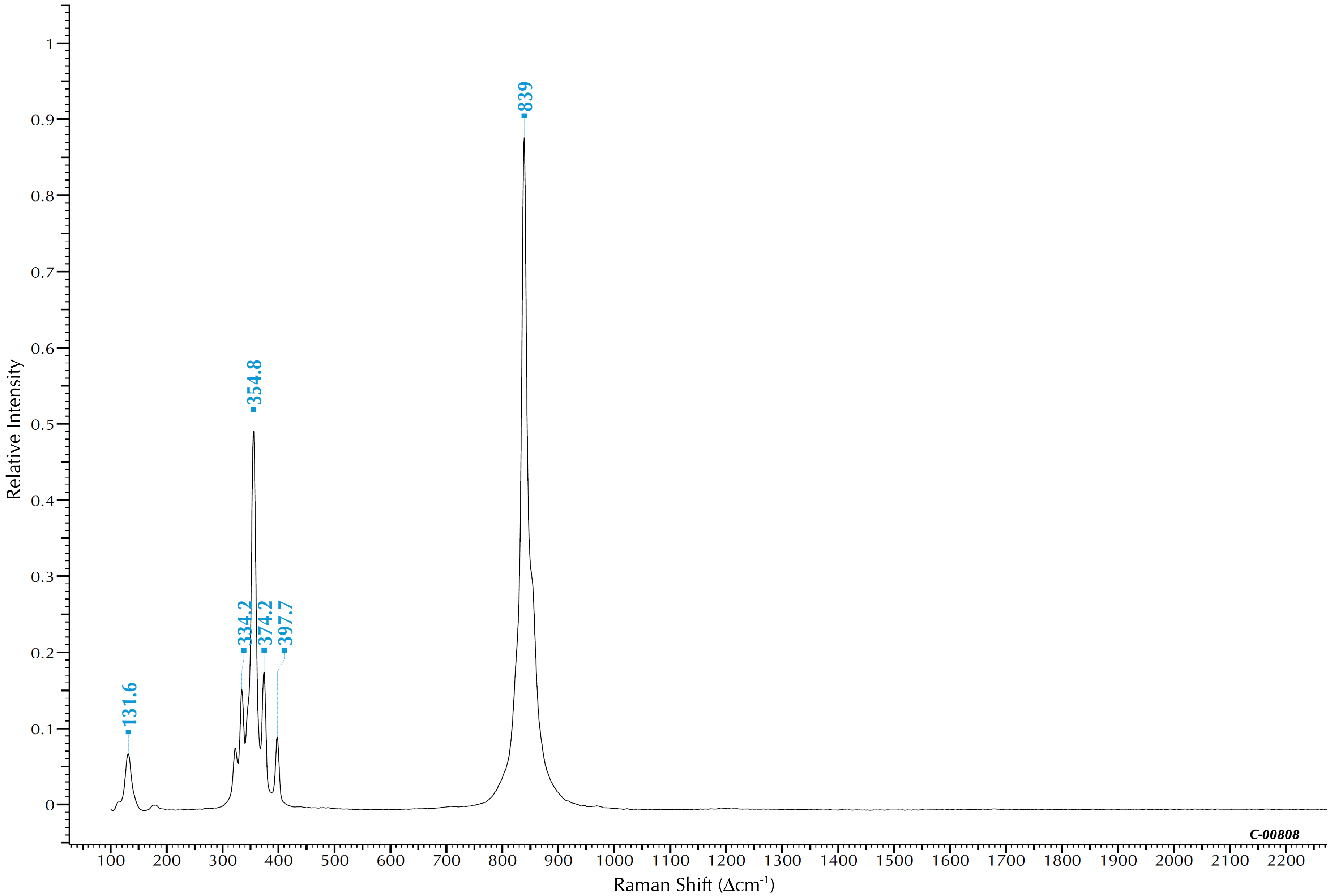
Chemical Category: Inorganic - Chromate
Constitution Number: 77893

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 4

Microtrace LLC

C.I. Pigment Yellow 34



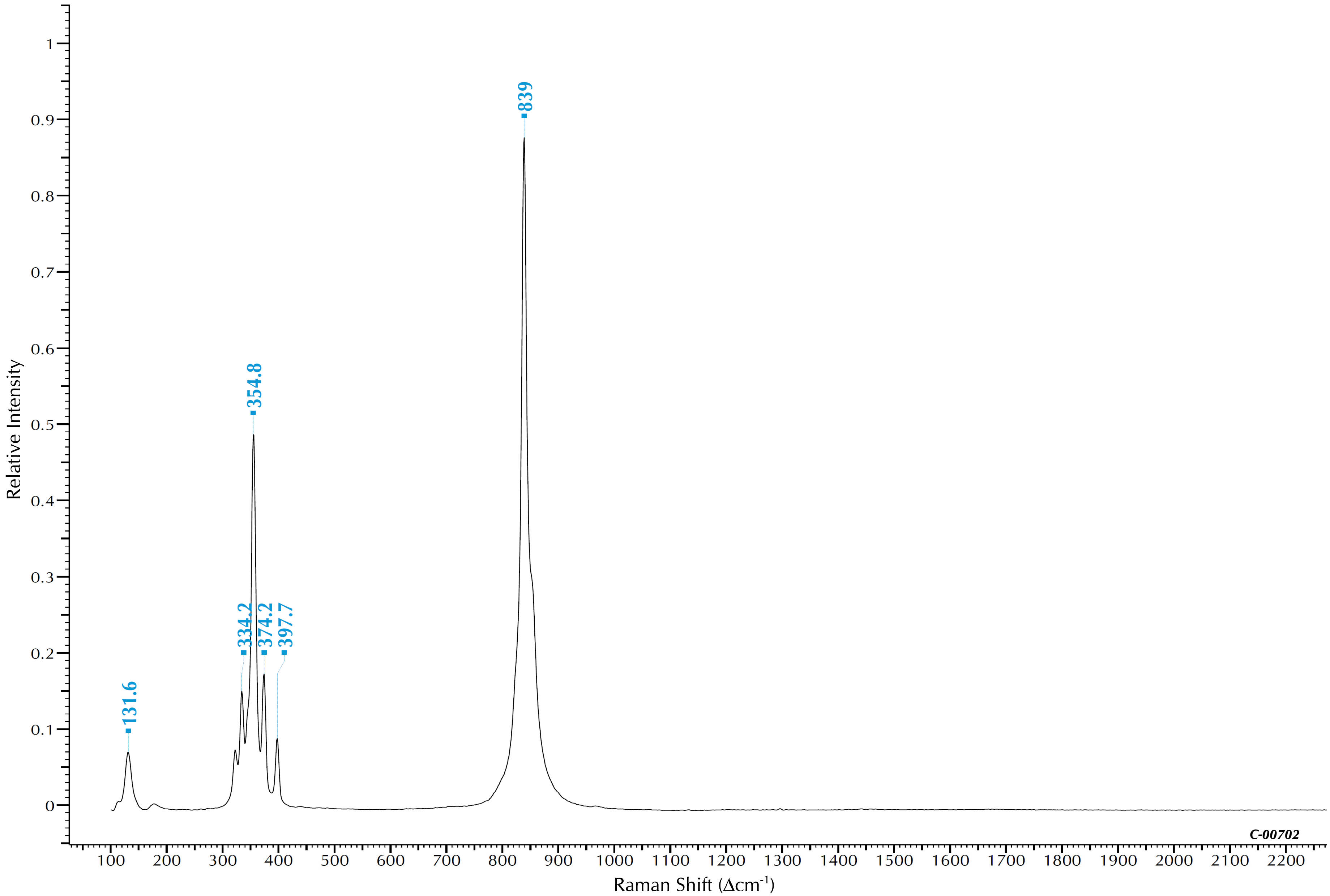
Chemical Category: Inorganic - Chromate
Constitution Number: 77600 77603

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 34:1



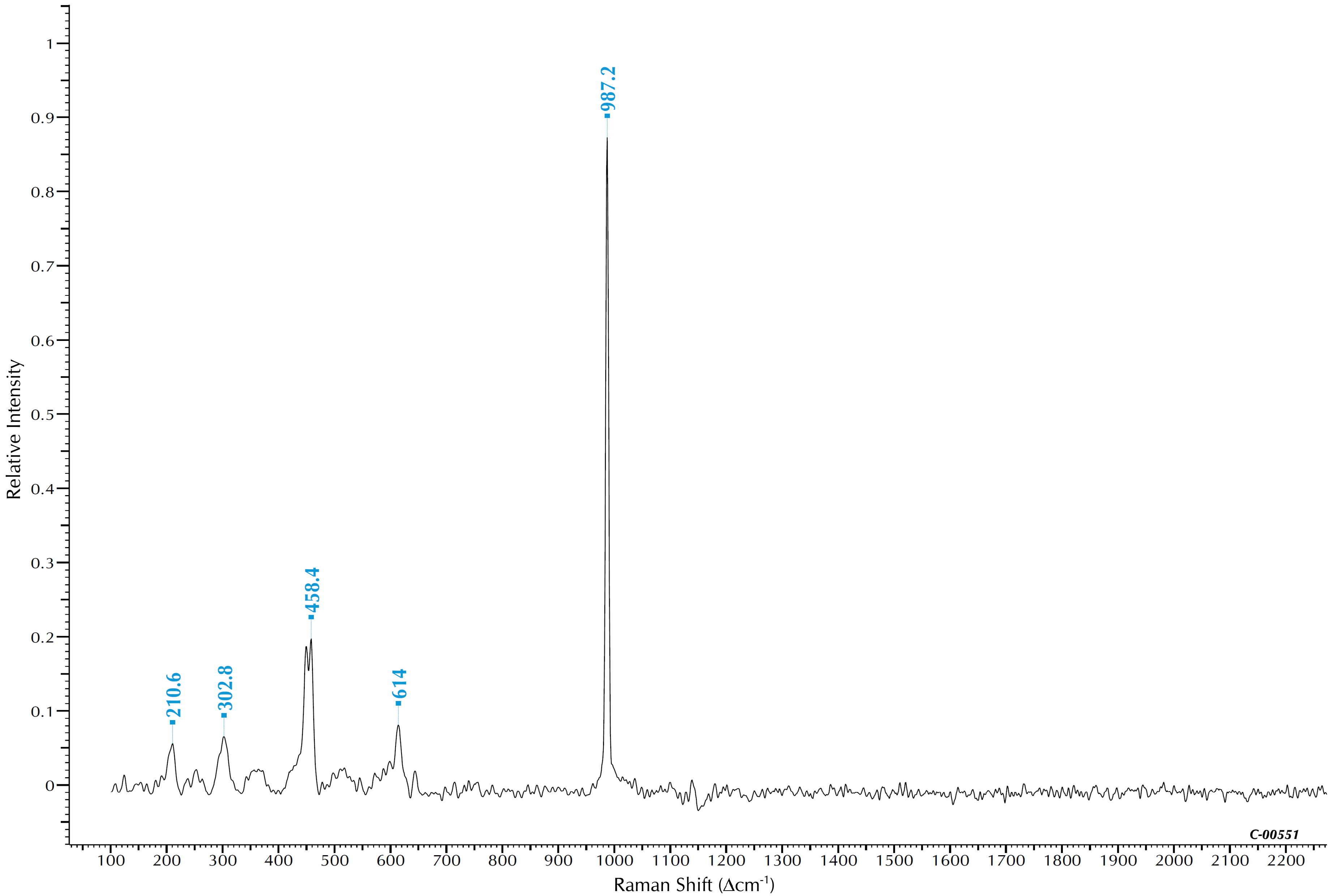
Chemical Category: Inorganic - Chromate
Constitution Number: 77603:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 35



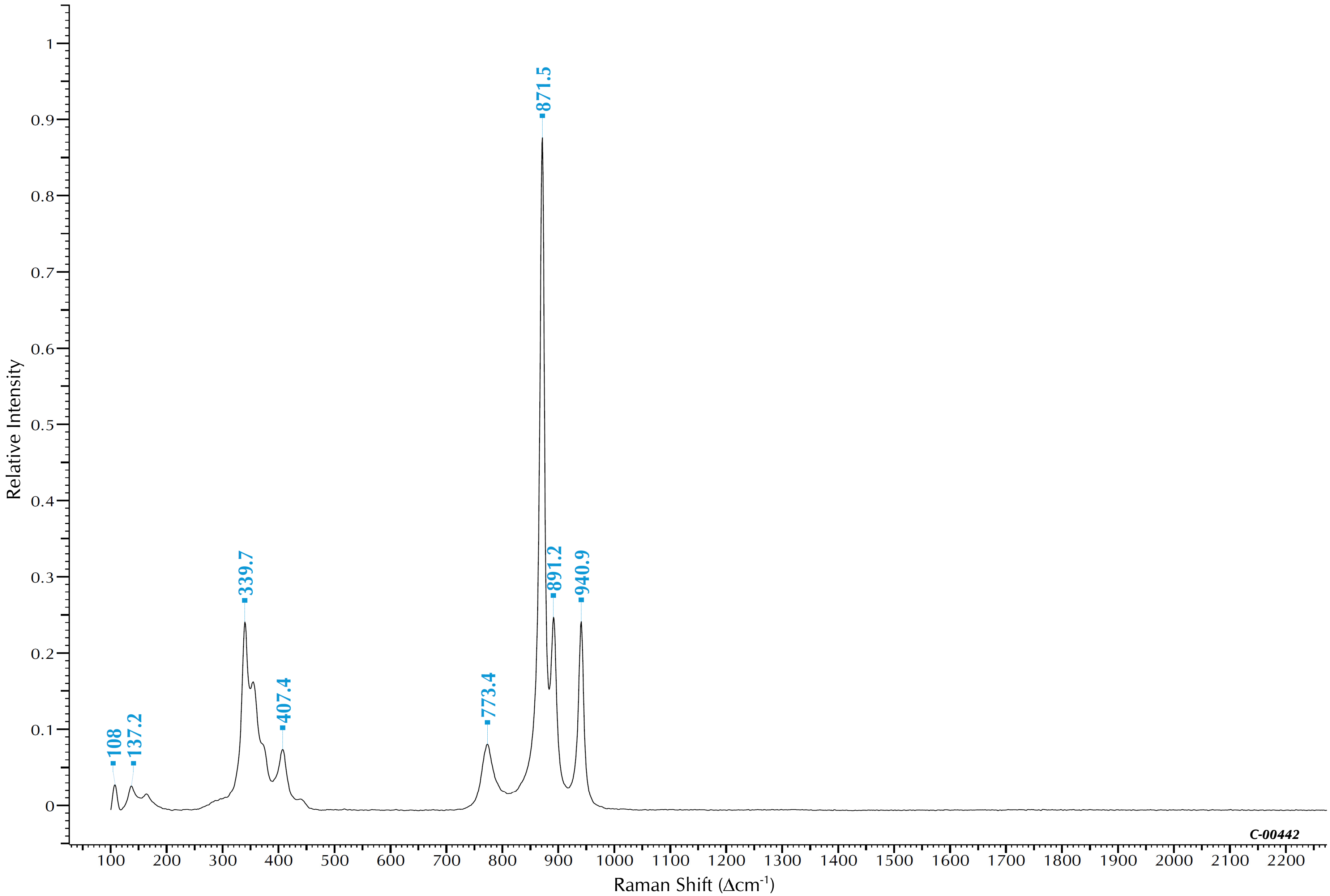
Chemical Category: Inorganic - Sulfate
Constitution Number: 77205

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 4

Microtrace LLC

C.I. Pigment Yellow 36



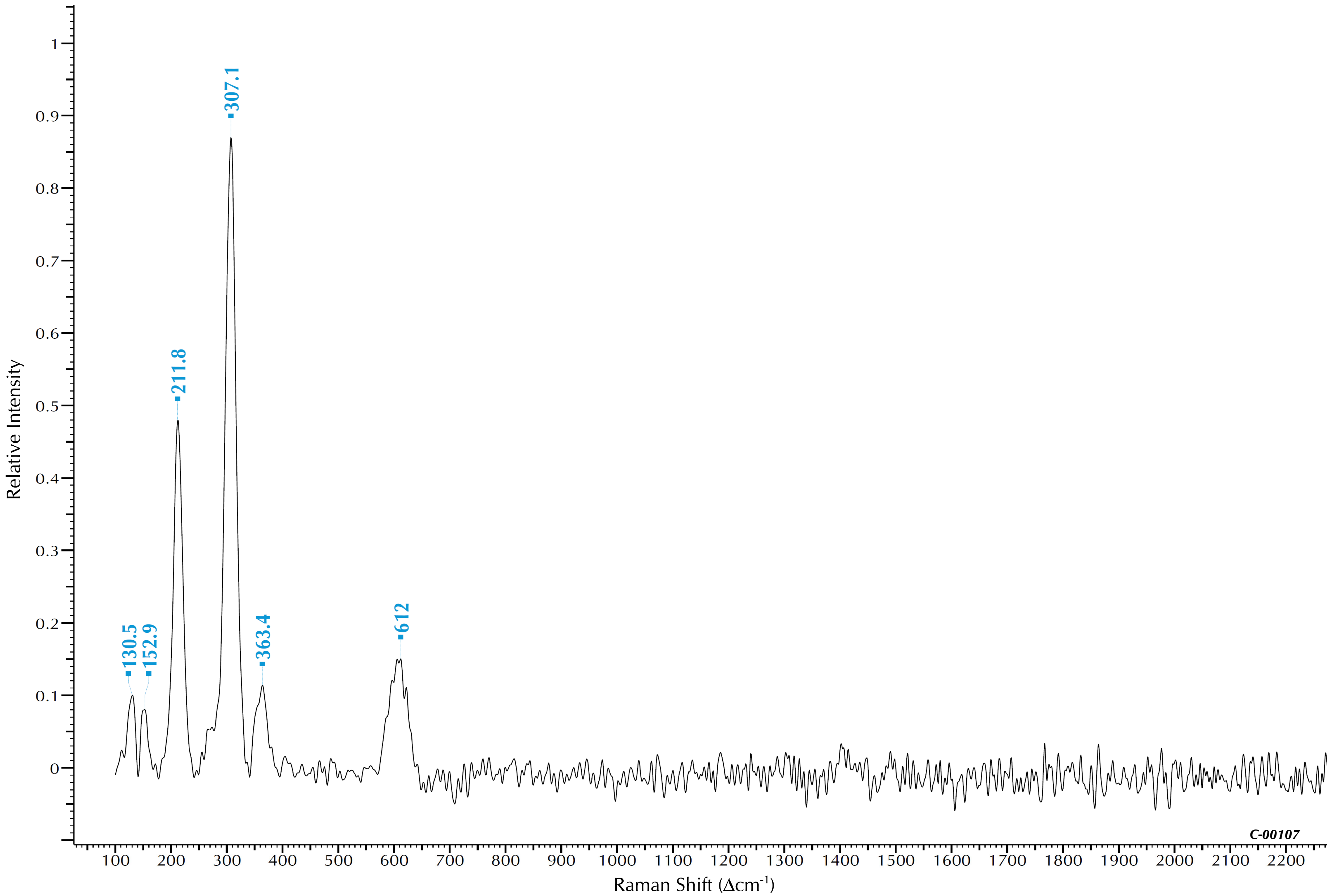
Chemical Category: Inorganic - Chromate
Constitution Number: 77955

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 4

Microtrace LLC

C.I. Pigment Yellow 37



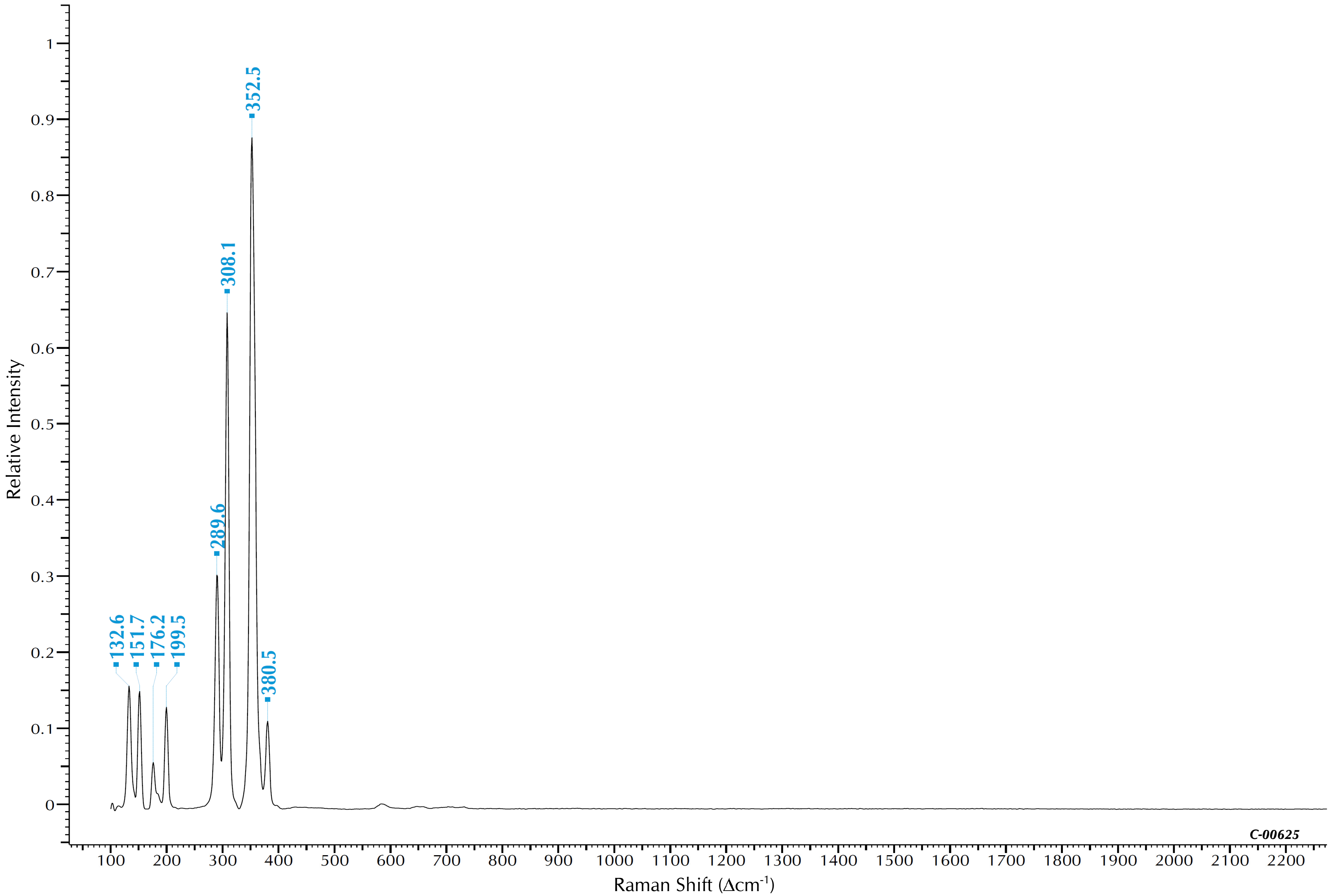
Chemical Category: Inorganic - Sulfide
Constitution Number: 77199

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 39



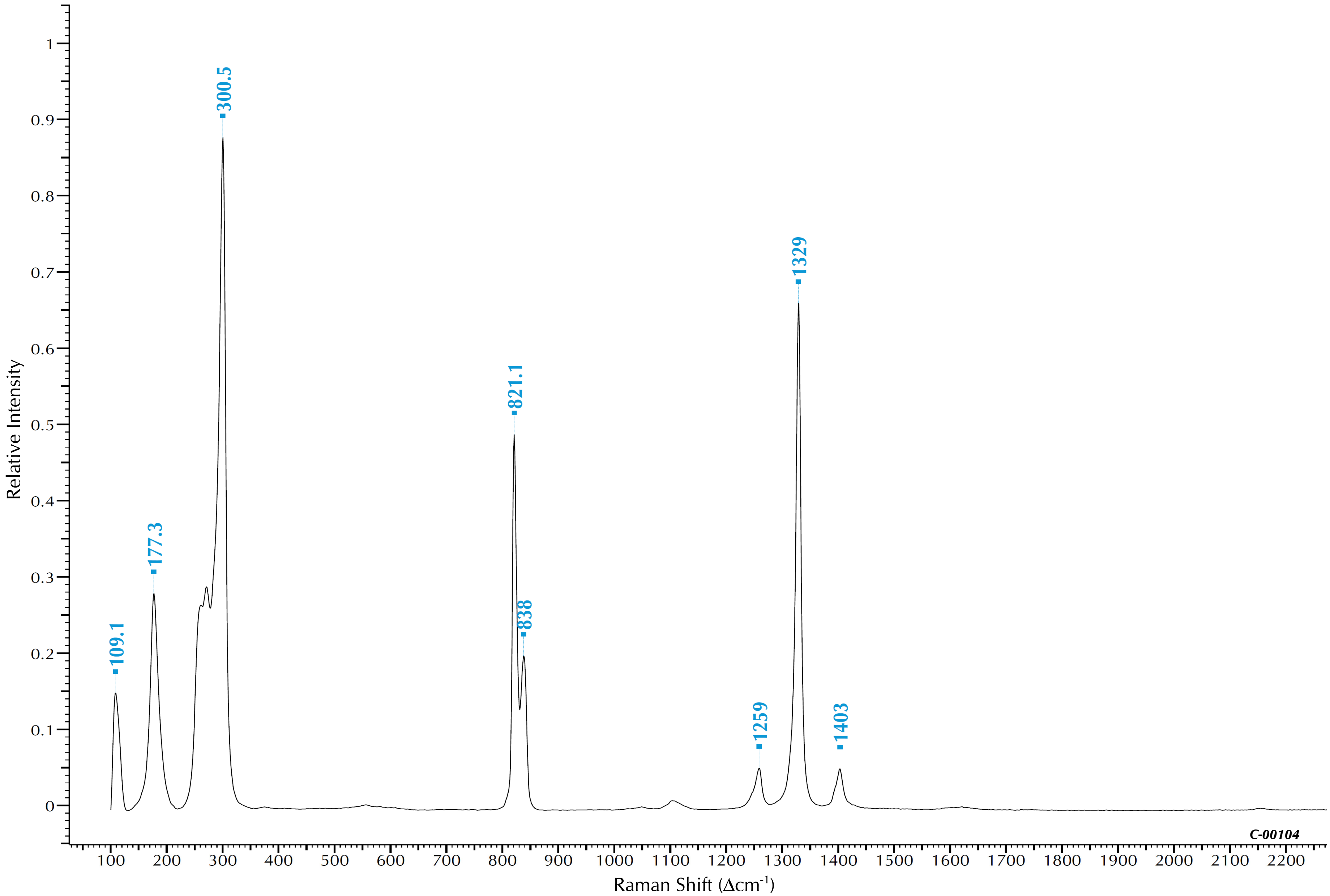
Chemical Category: Inorganic - Sulfide
Constitution Number: 77085 77086

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 40



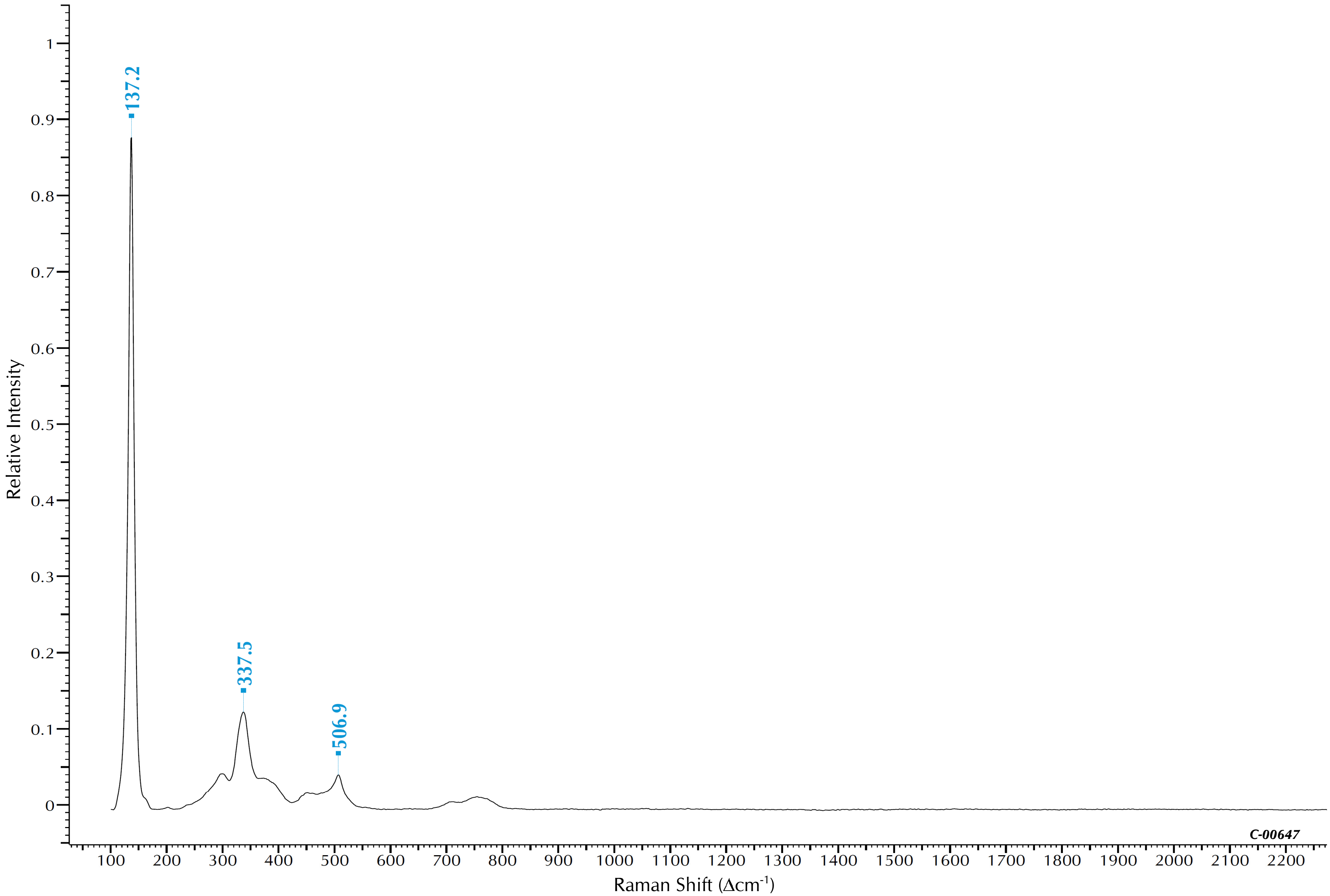
Chemical Category: Inorganic - Nitro
Constitution Number: 77357

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 41



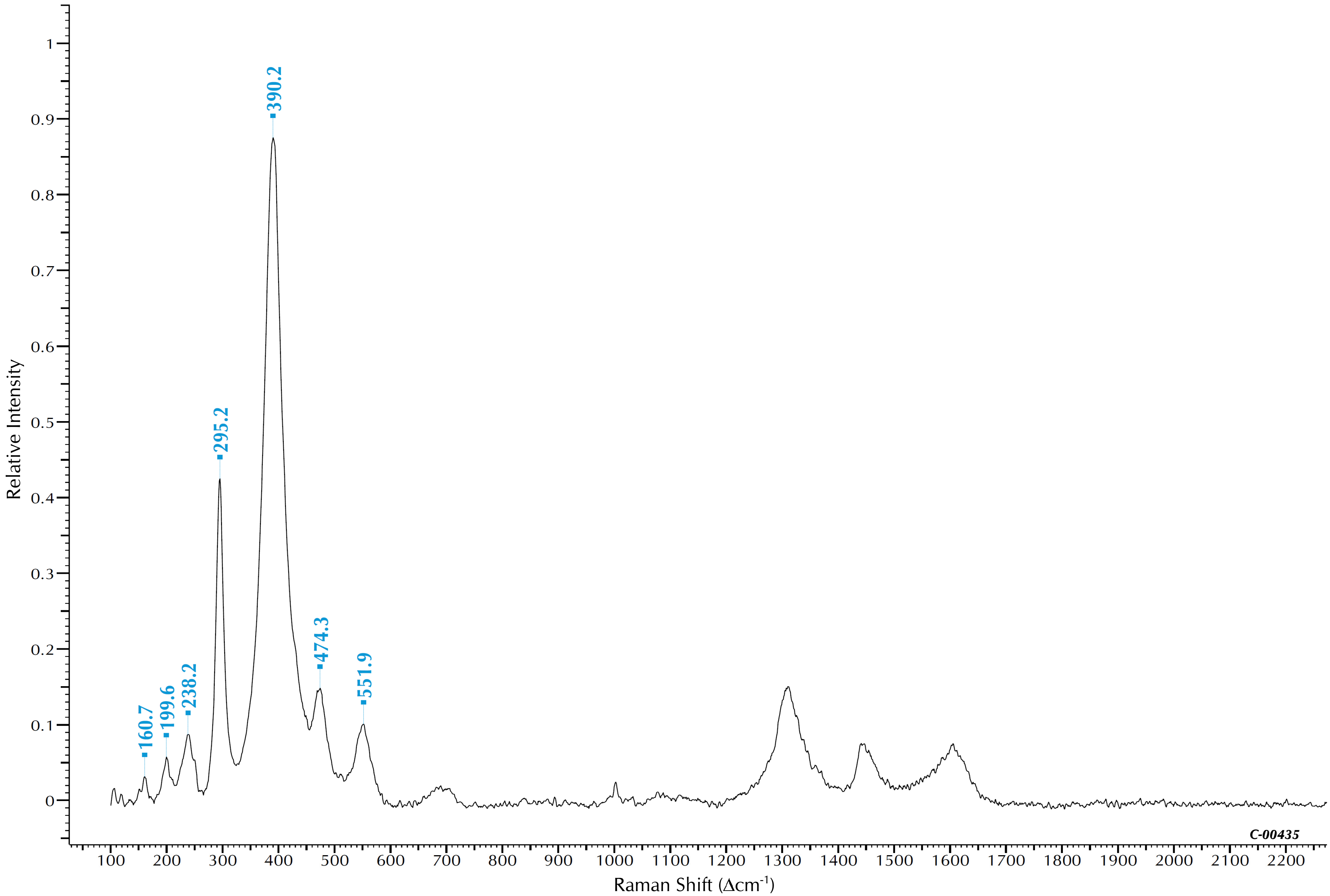
Chemical Category: Inorganic - Oxide
Constitution Number: 77588 77589

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 4

Microtrace LLC

C.I. Pigment Yellow 42 (α)



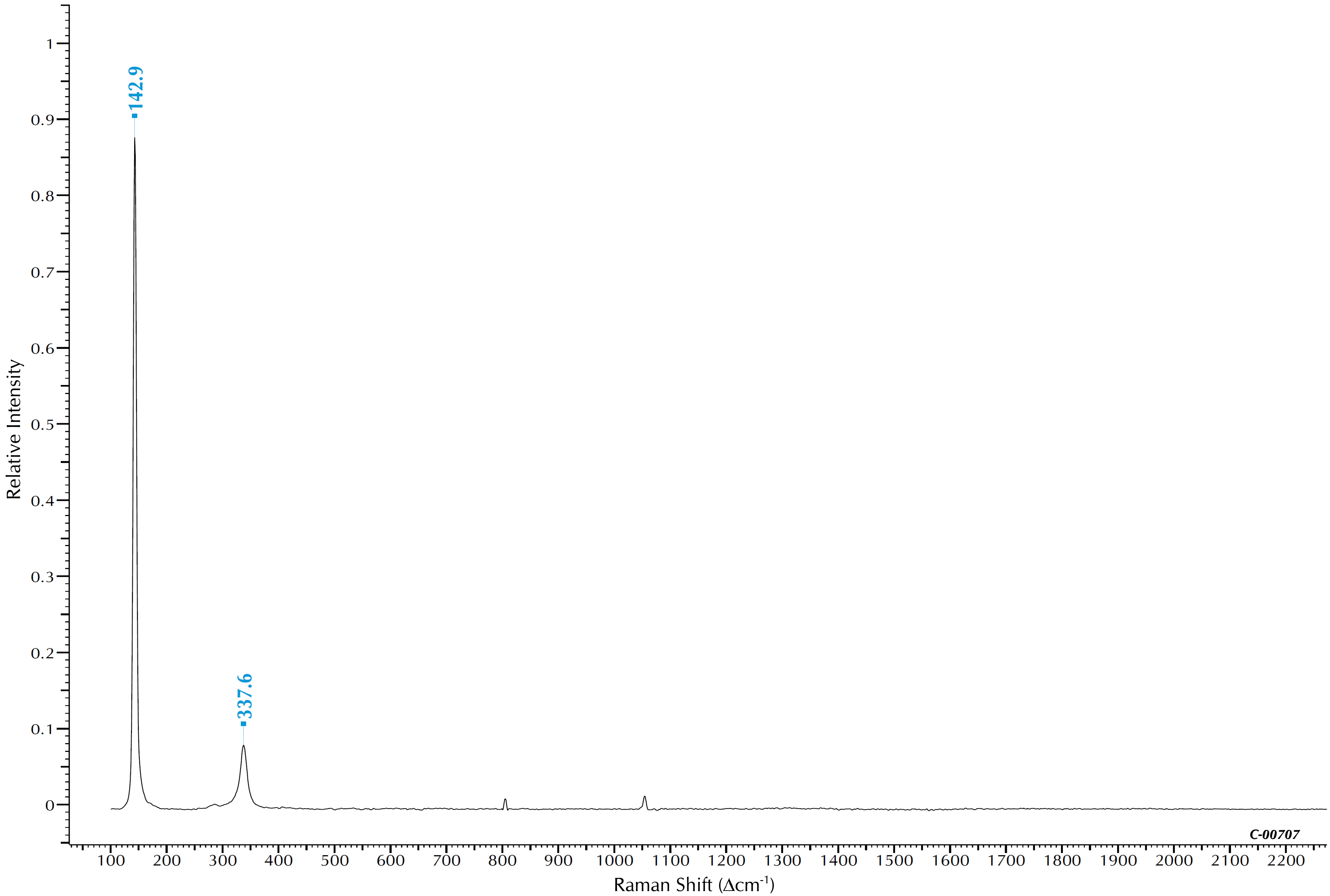
Chemical Category: Inorganic - Oxide
Constitution Number: 77492

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 5

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 46



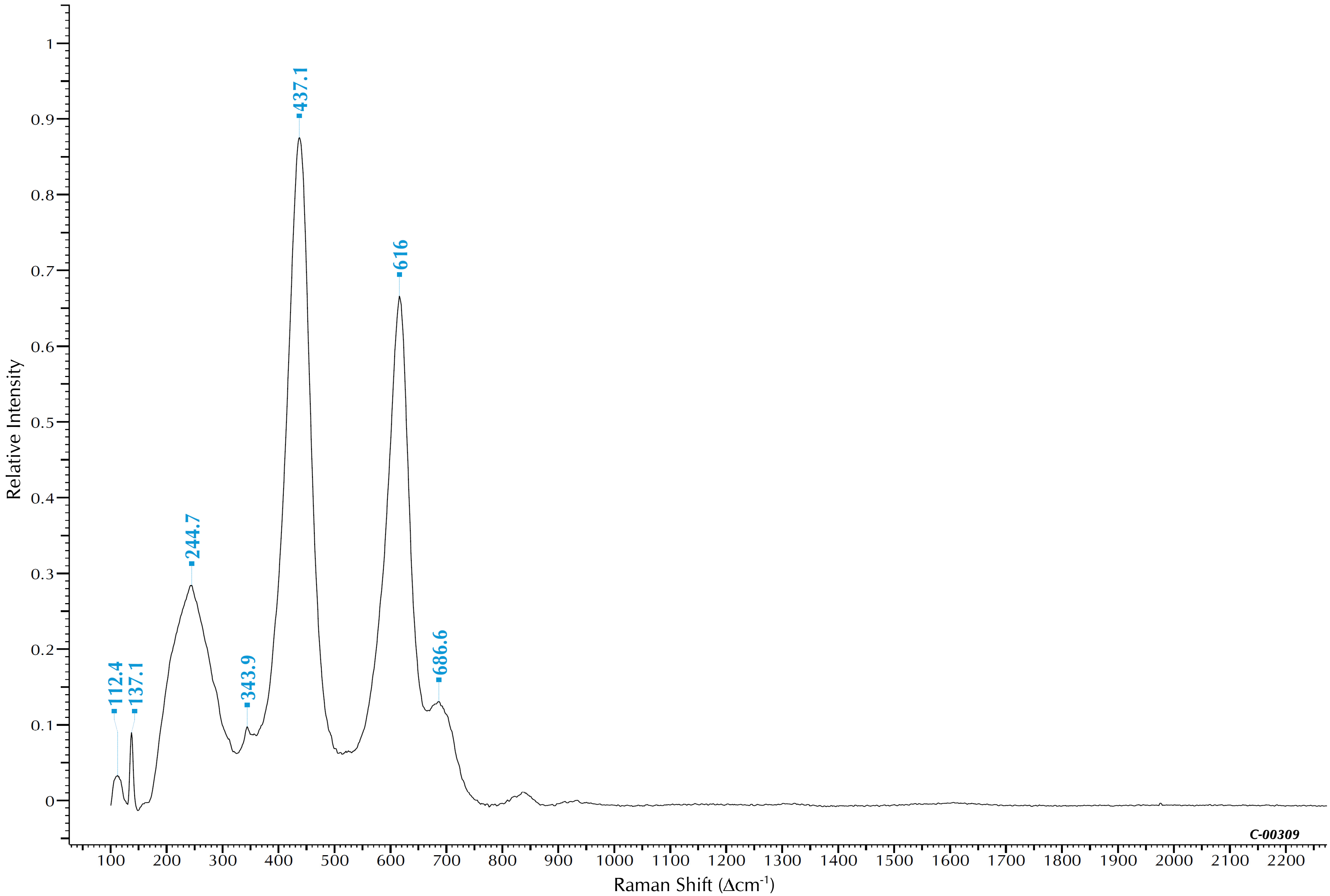
Chemical Category: Inorganic - Oxide
Constitution Number: 77577

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 53



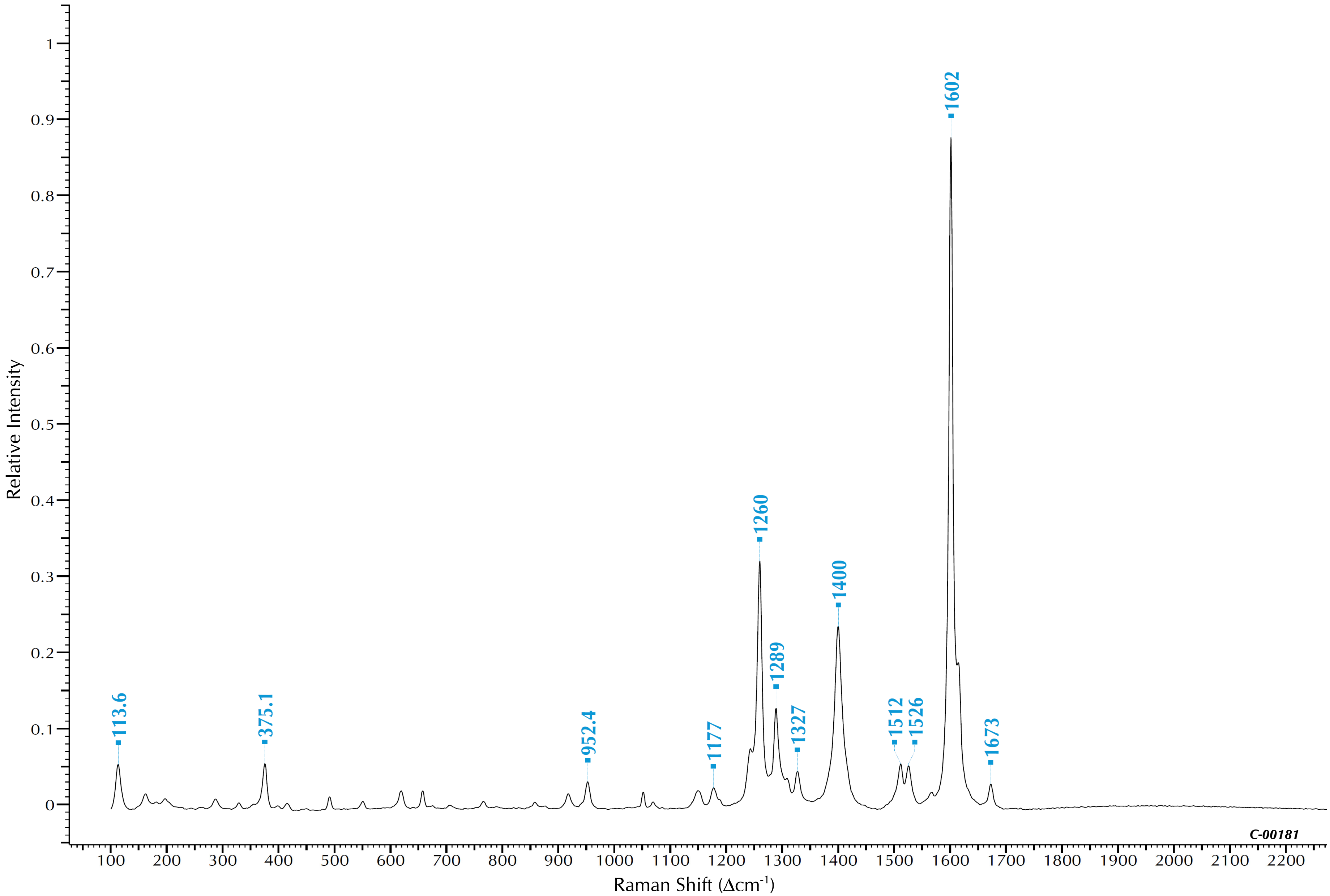
Chemical Category: Inorganic - Oxide
Constitution Number: 77788

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 55



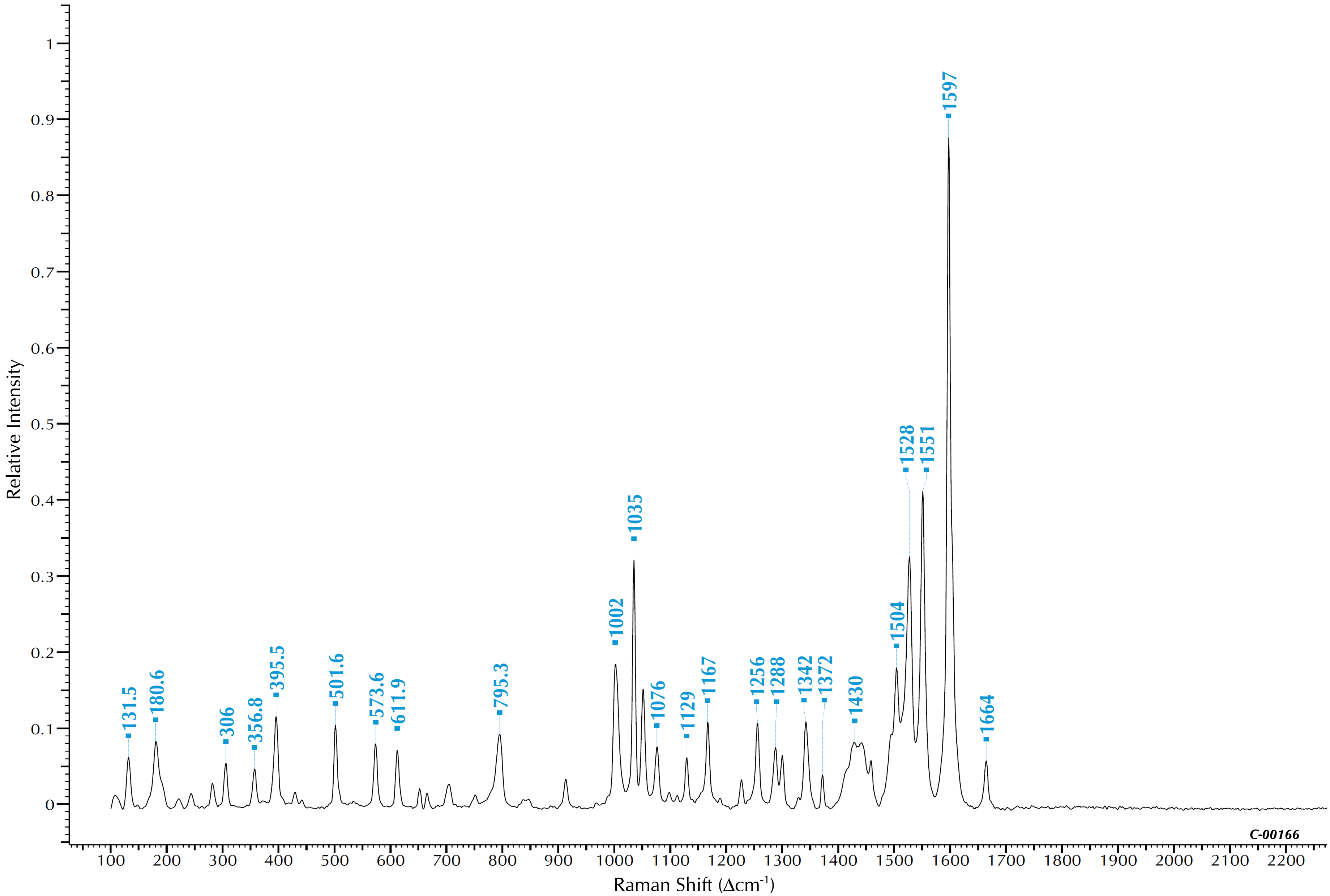
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21096

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 60



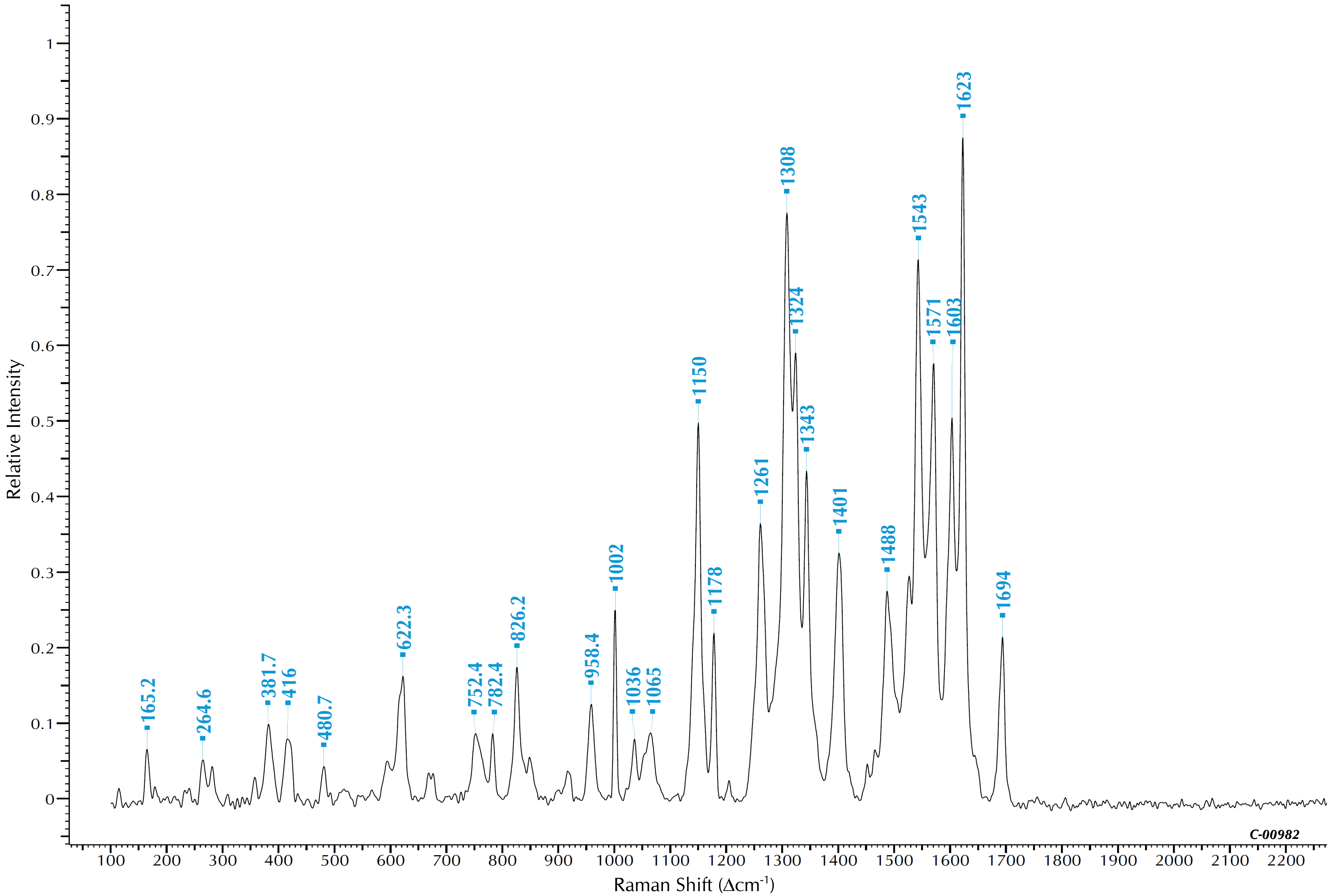
Chemical Category: Organic - Azo - Monoazo - Deviated
Constitution Number: 12705

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 61



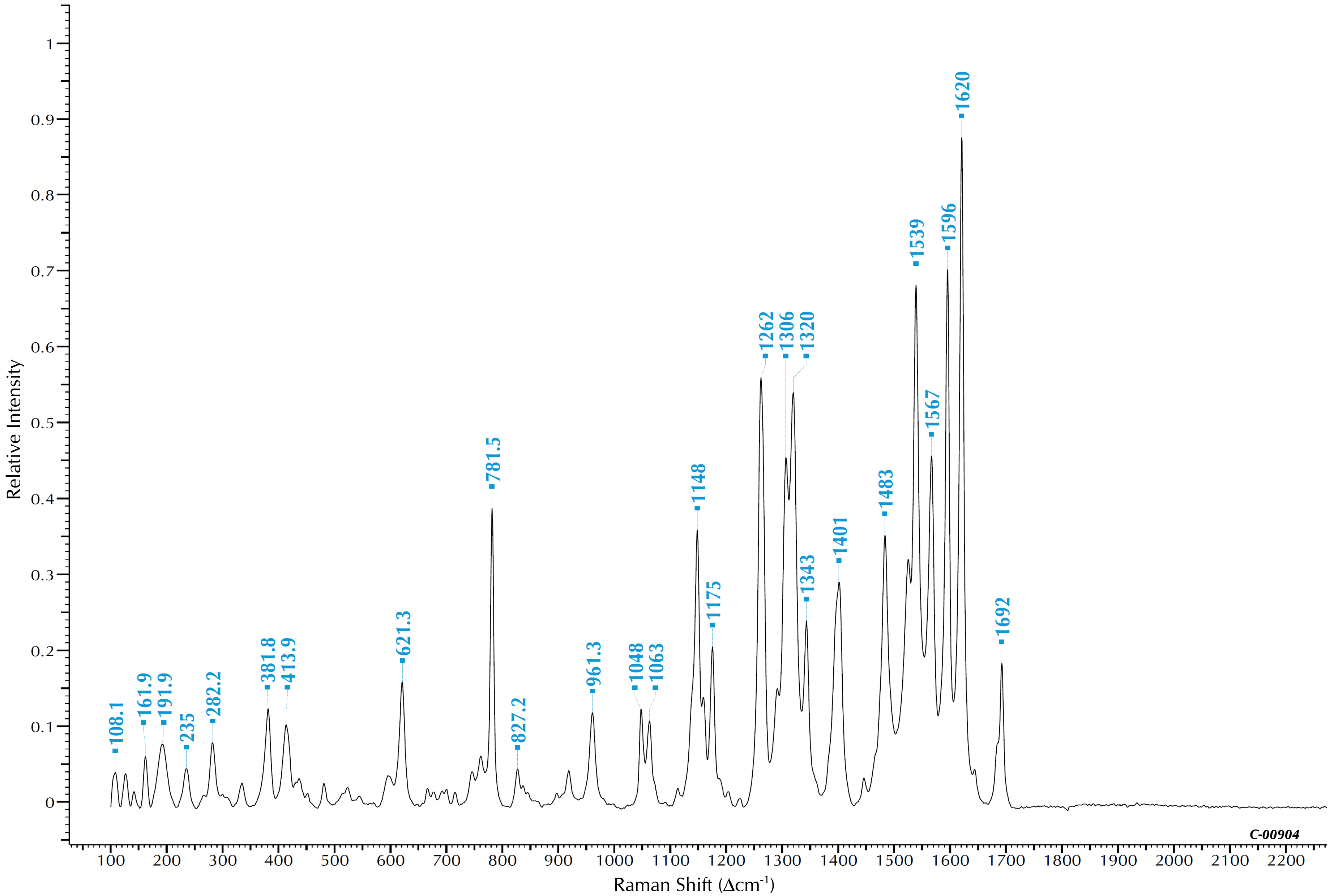
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 13880

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 62



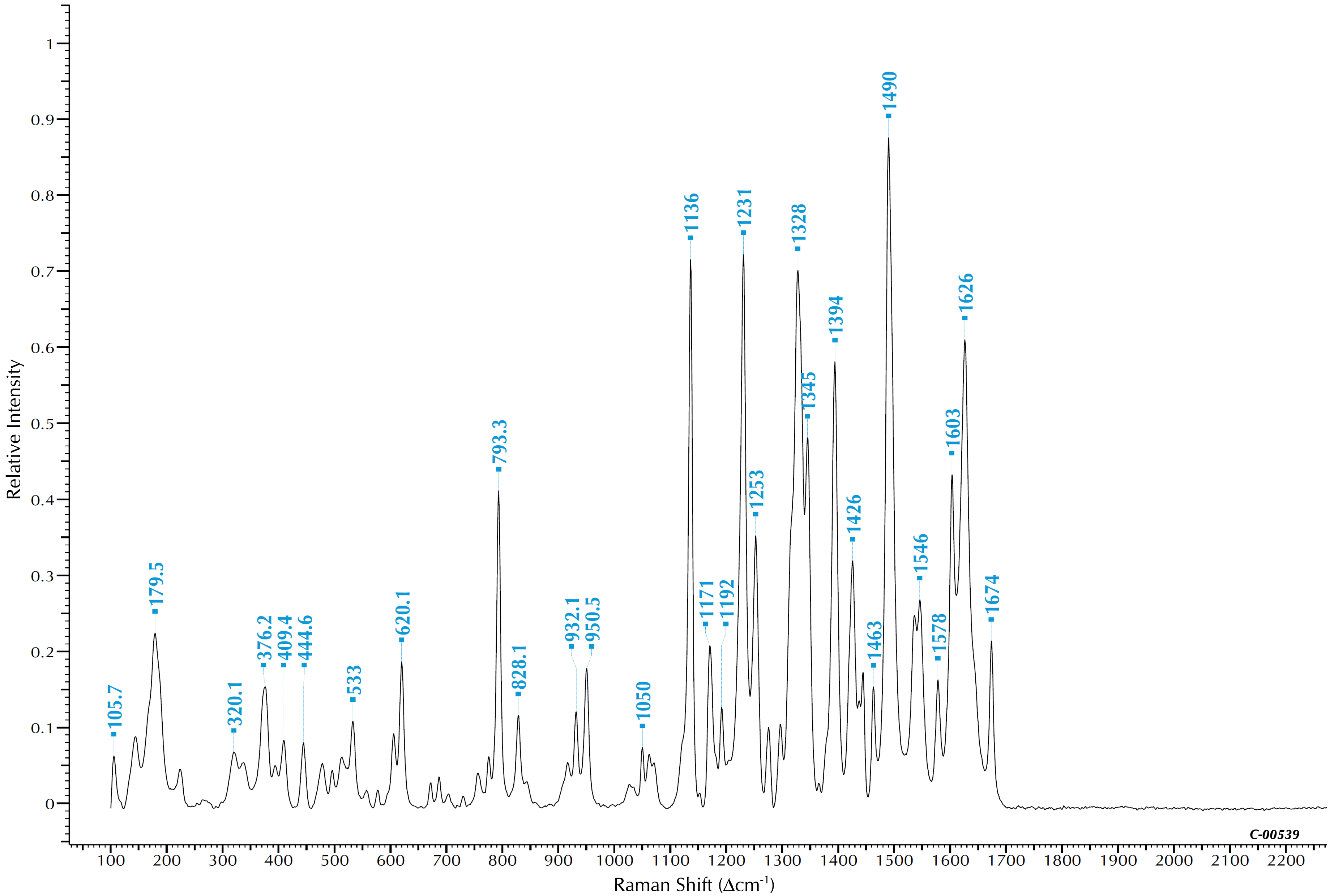
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 13940

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 65



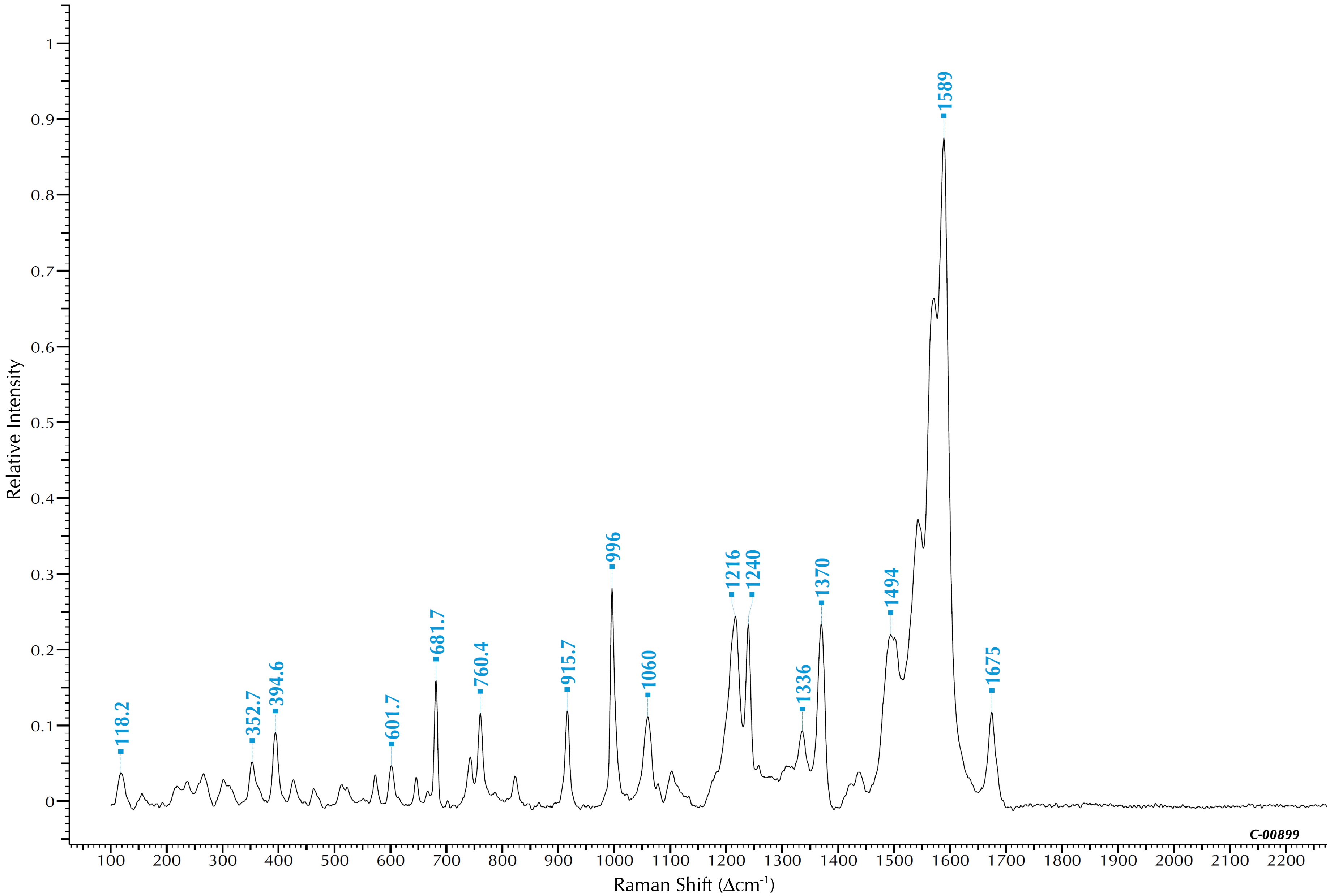
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11740

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 73



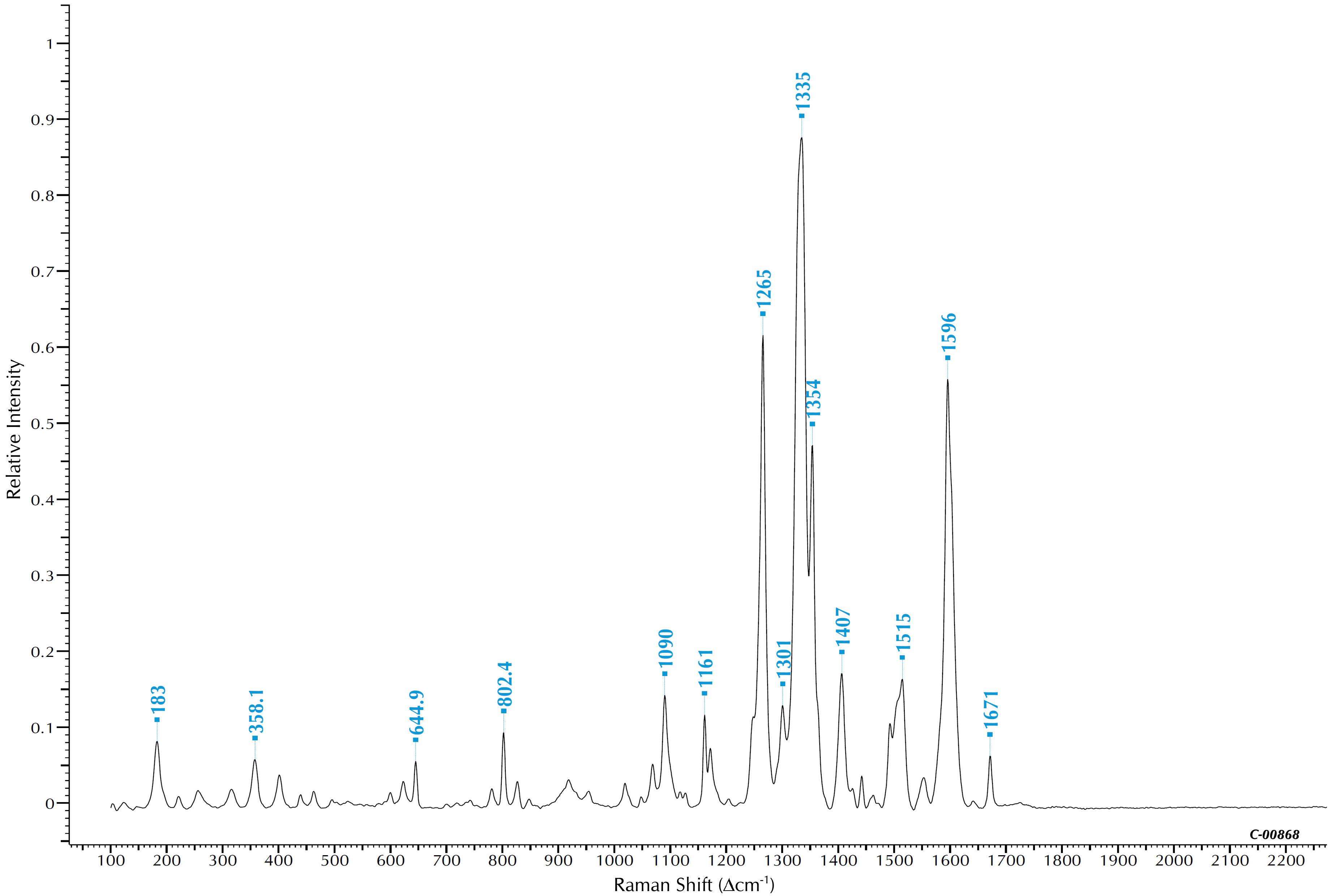
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11738

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 74



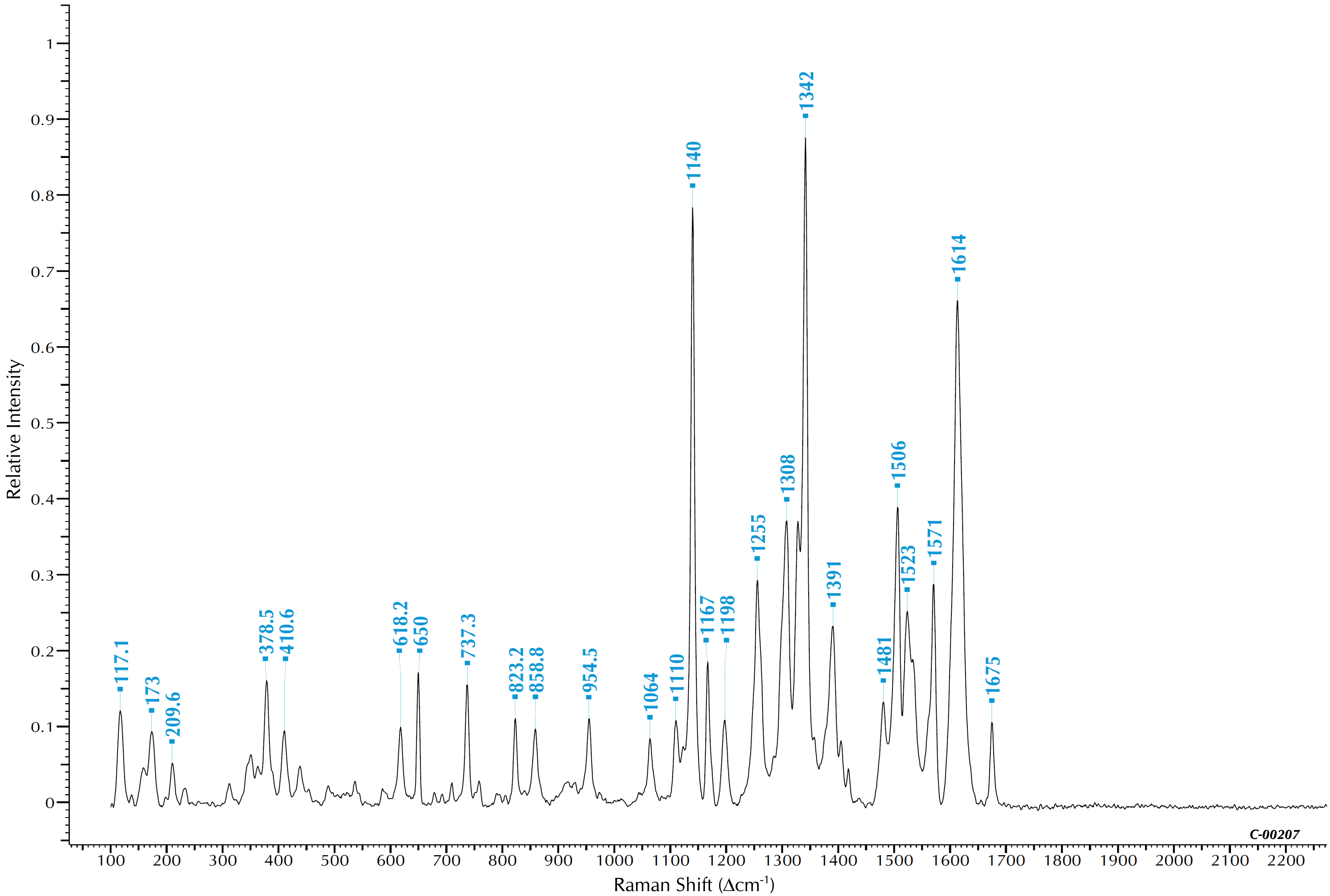
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11741

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 75



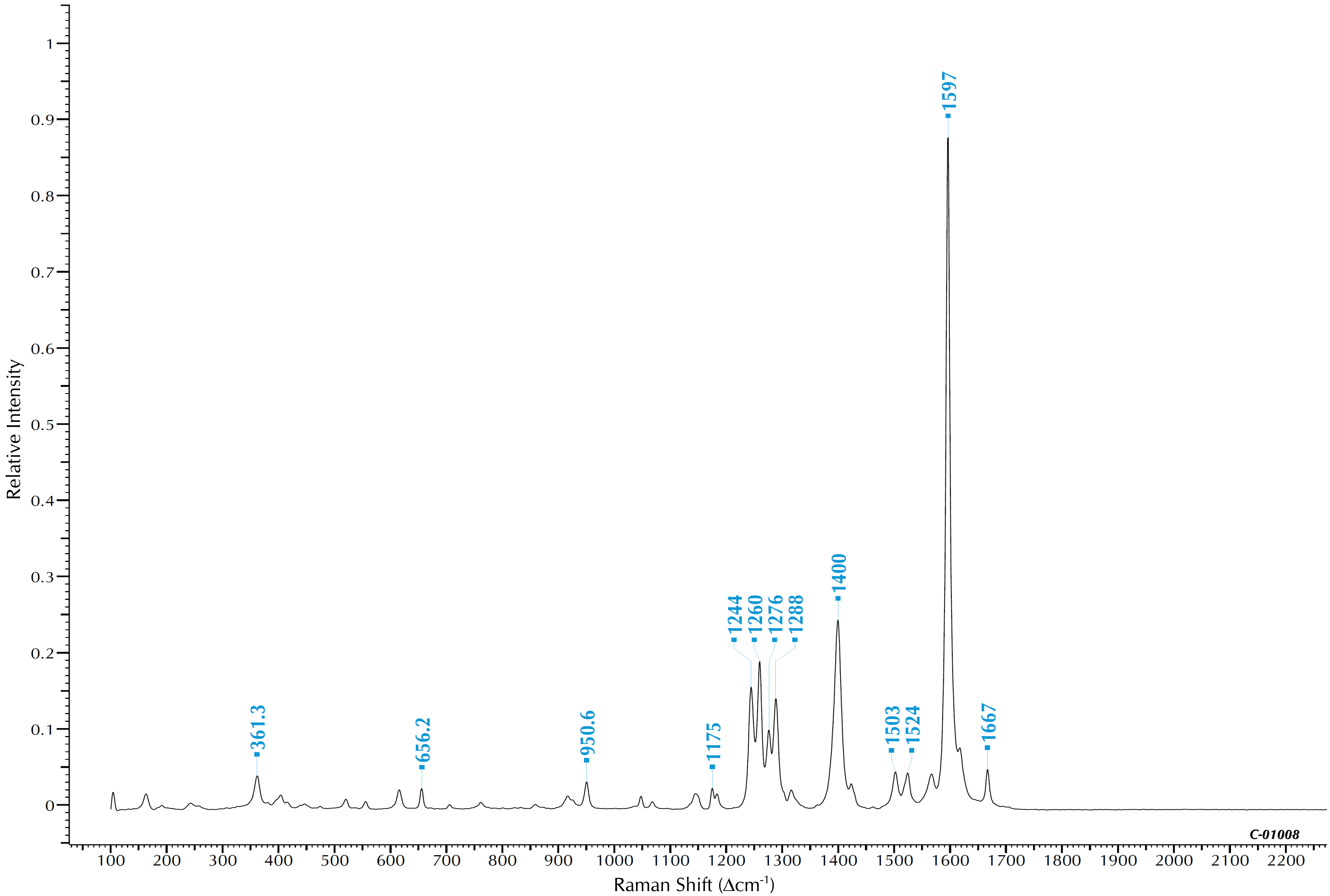
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11770

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 81



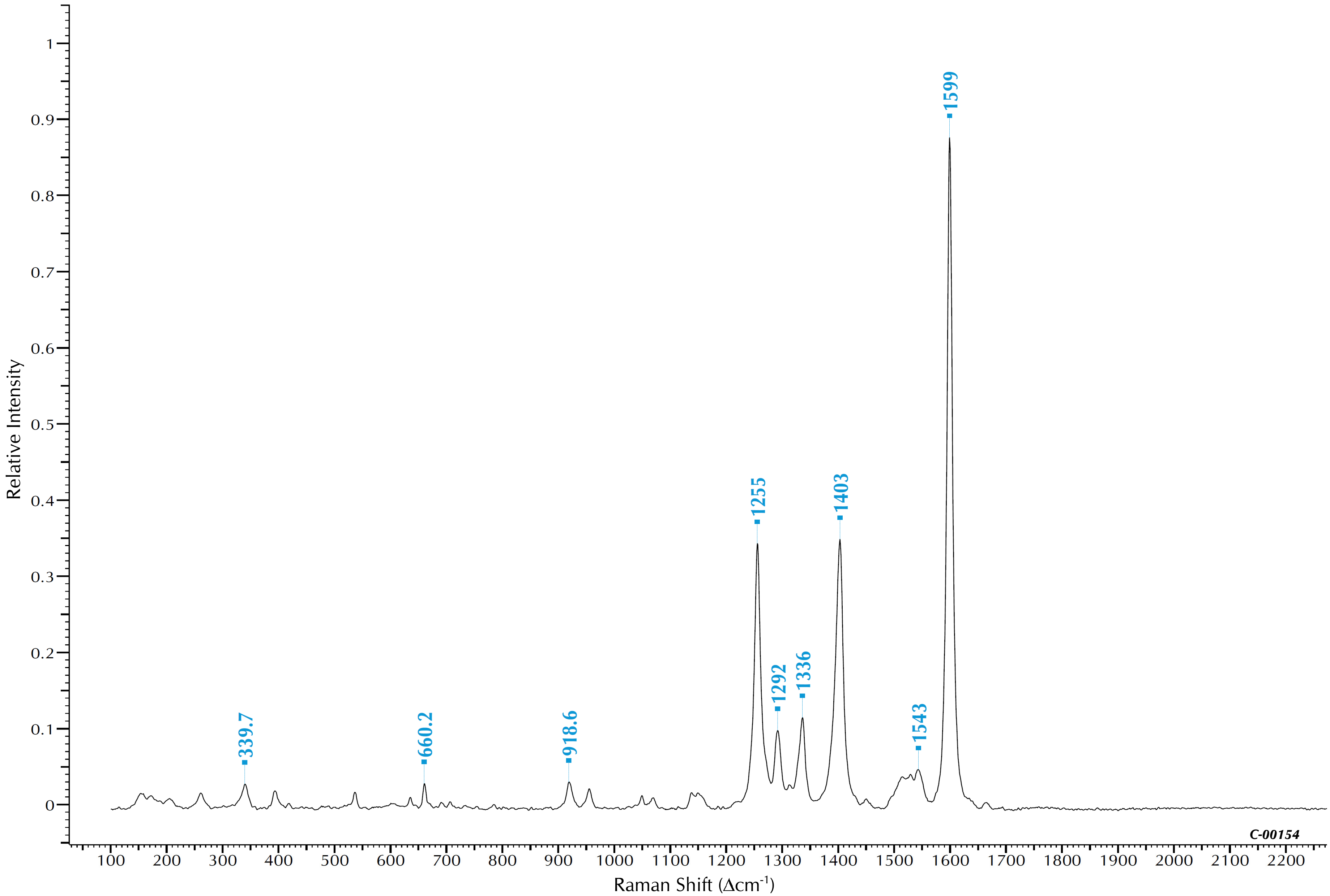
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21127

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 83



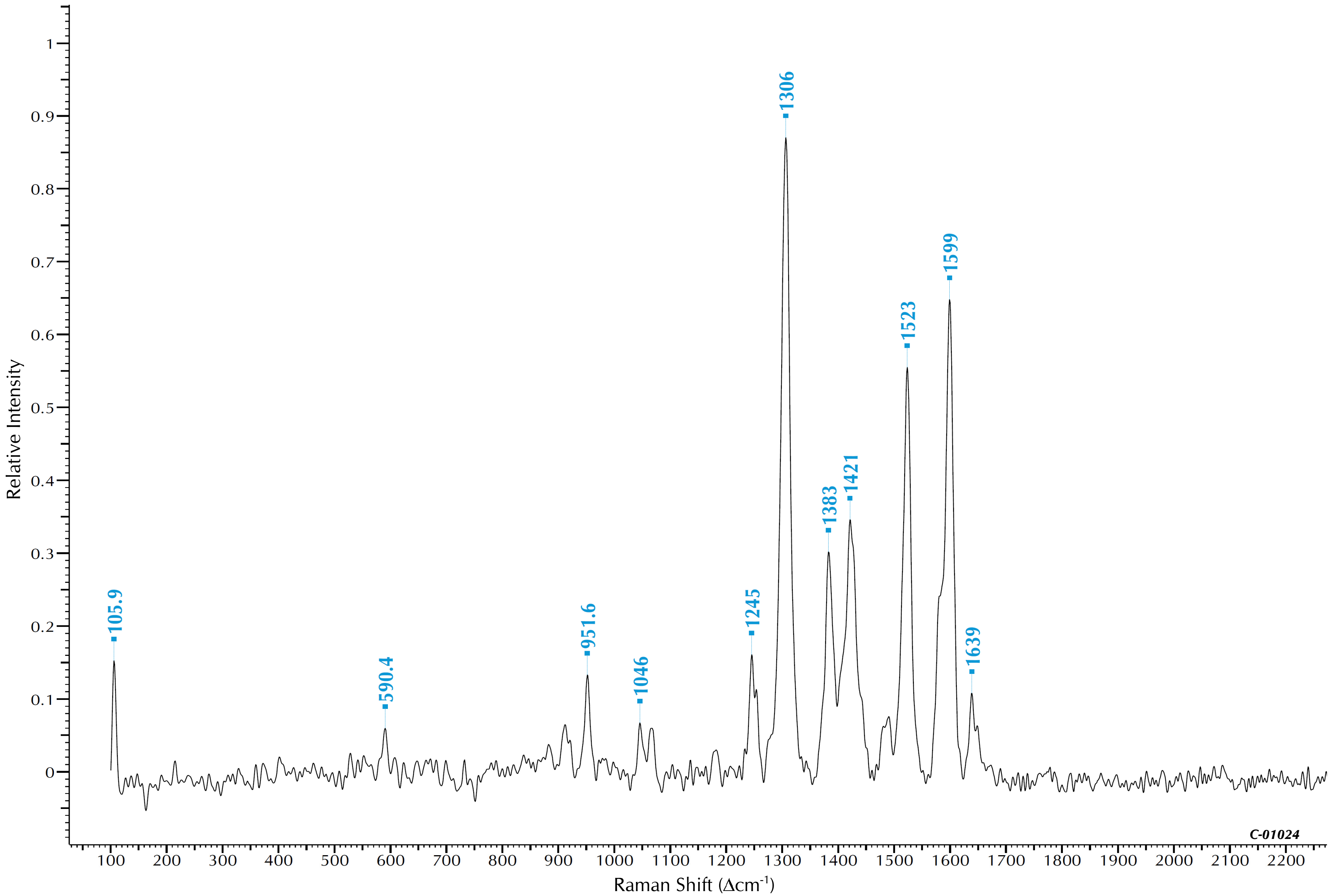
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21108

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 93



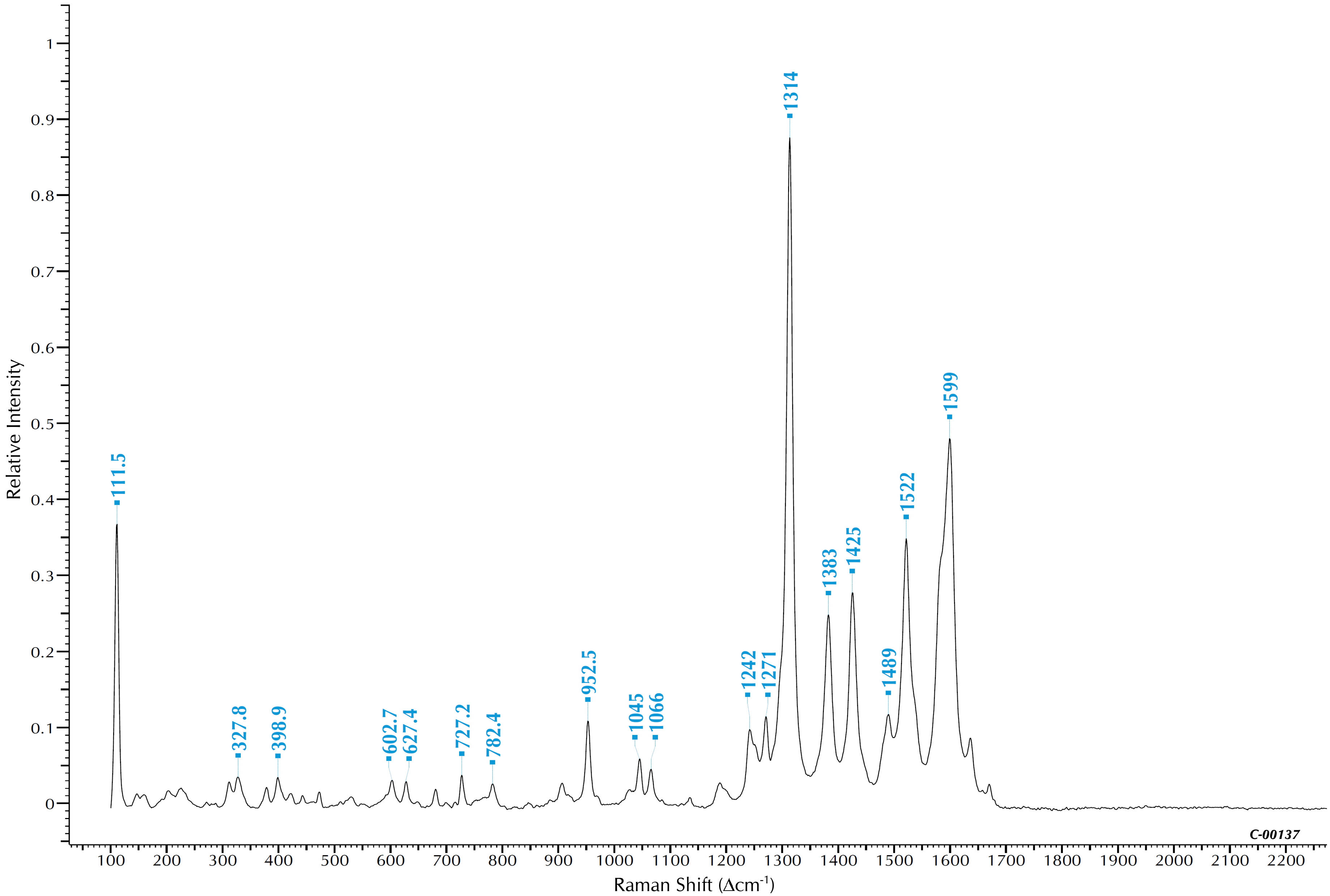
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20710

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 95



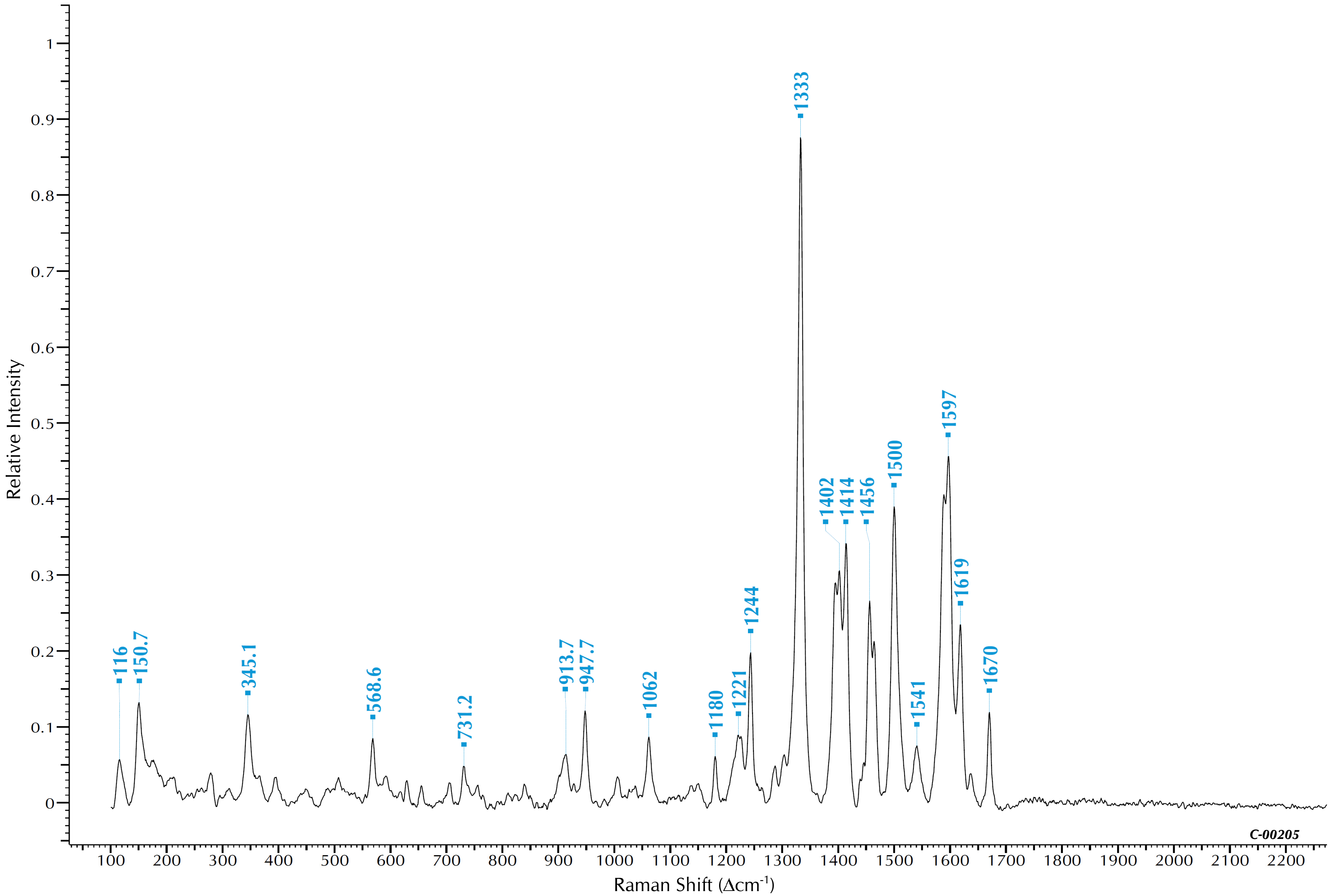
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20034

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 97



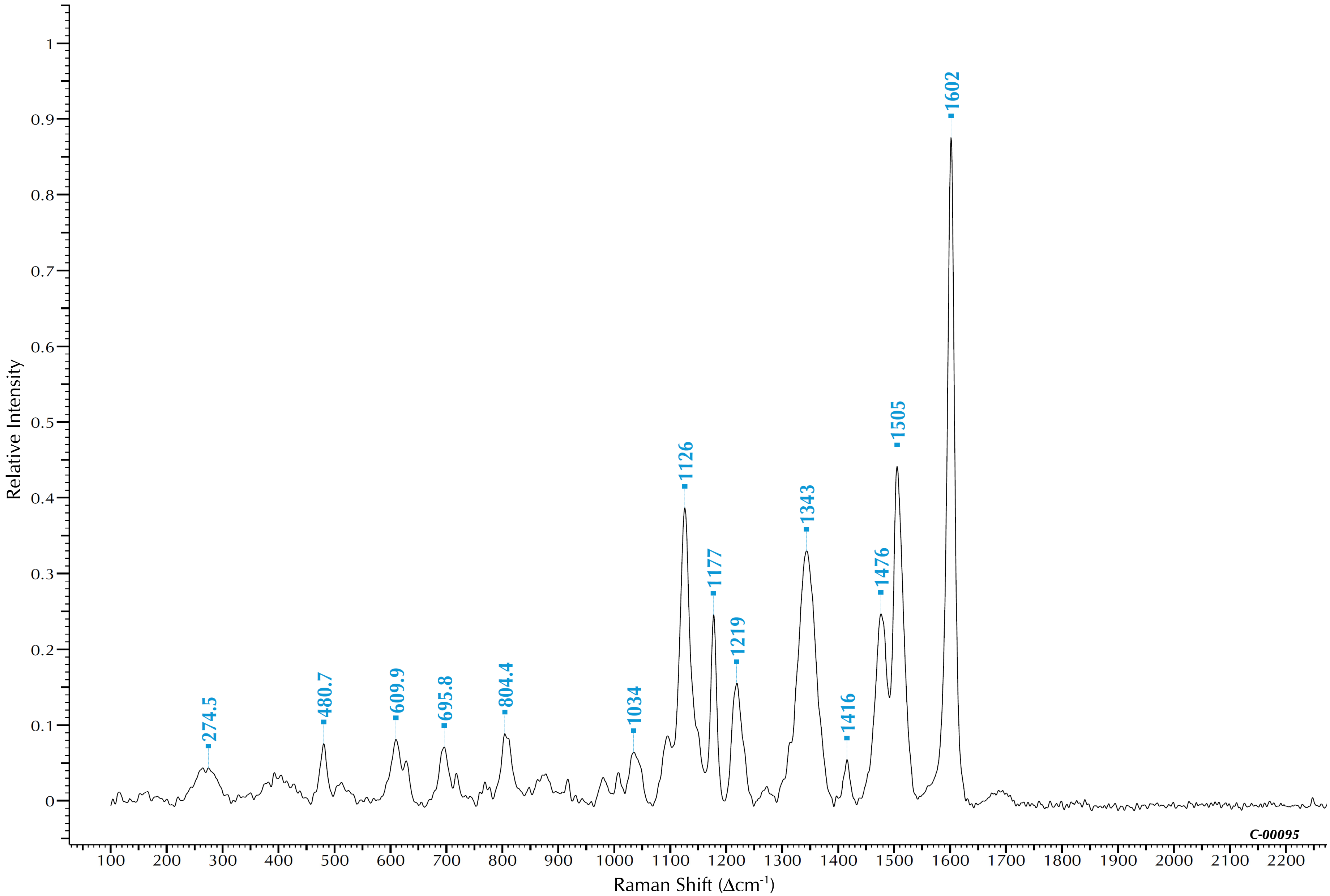
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11767

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 100



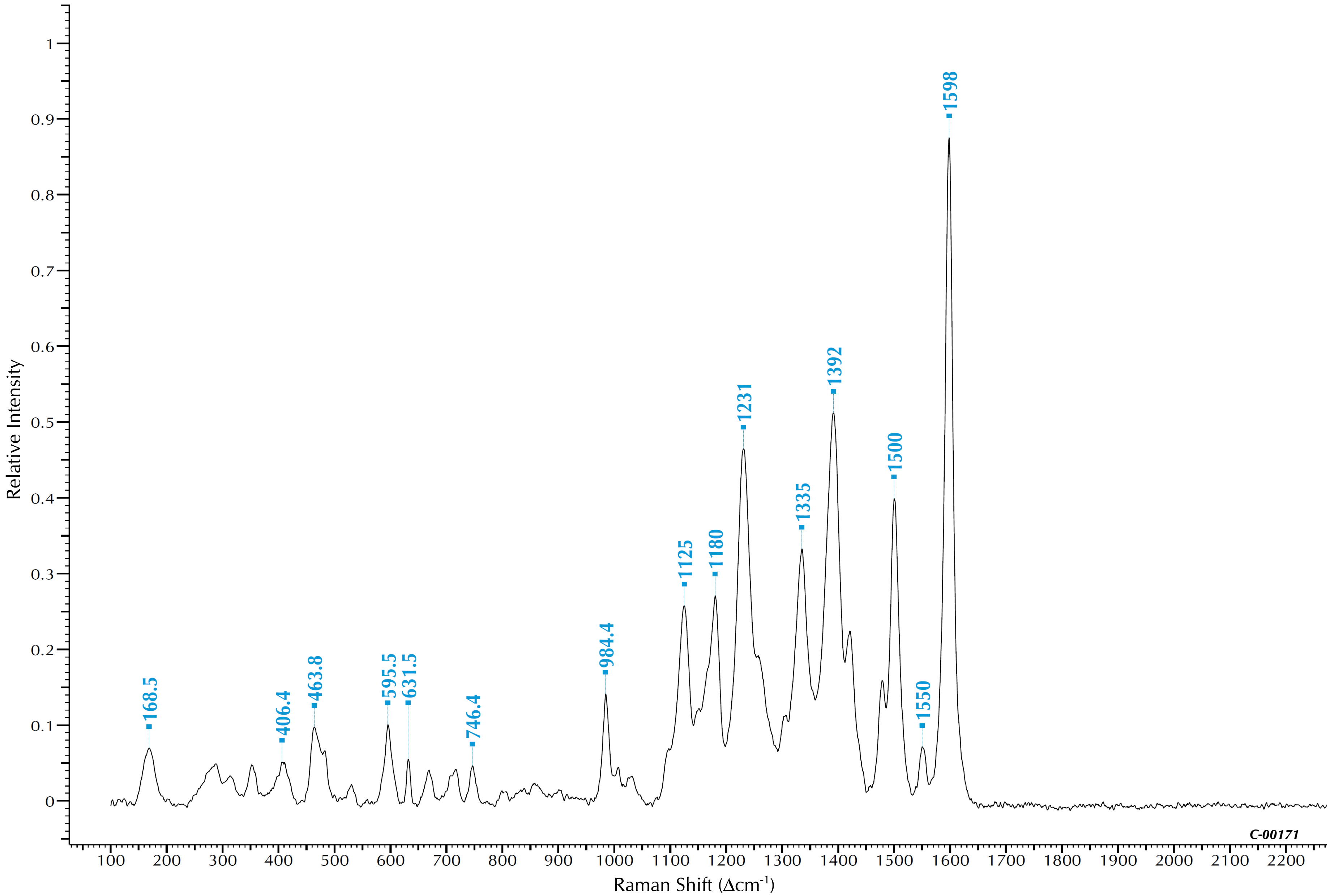
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 19140:1

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 104



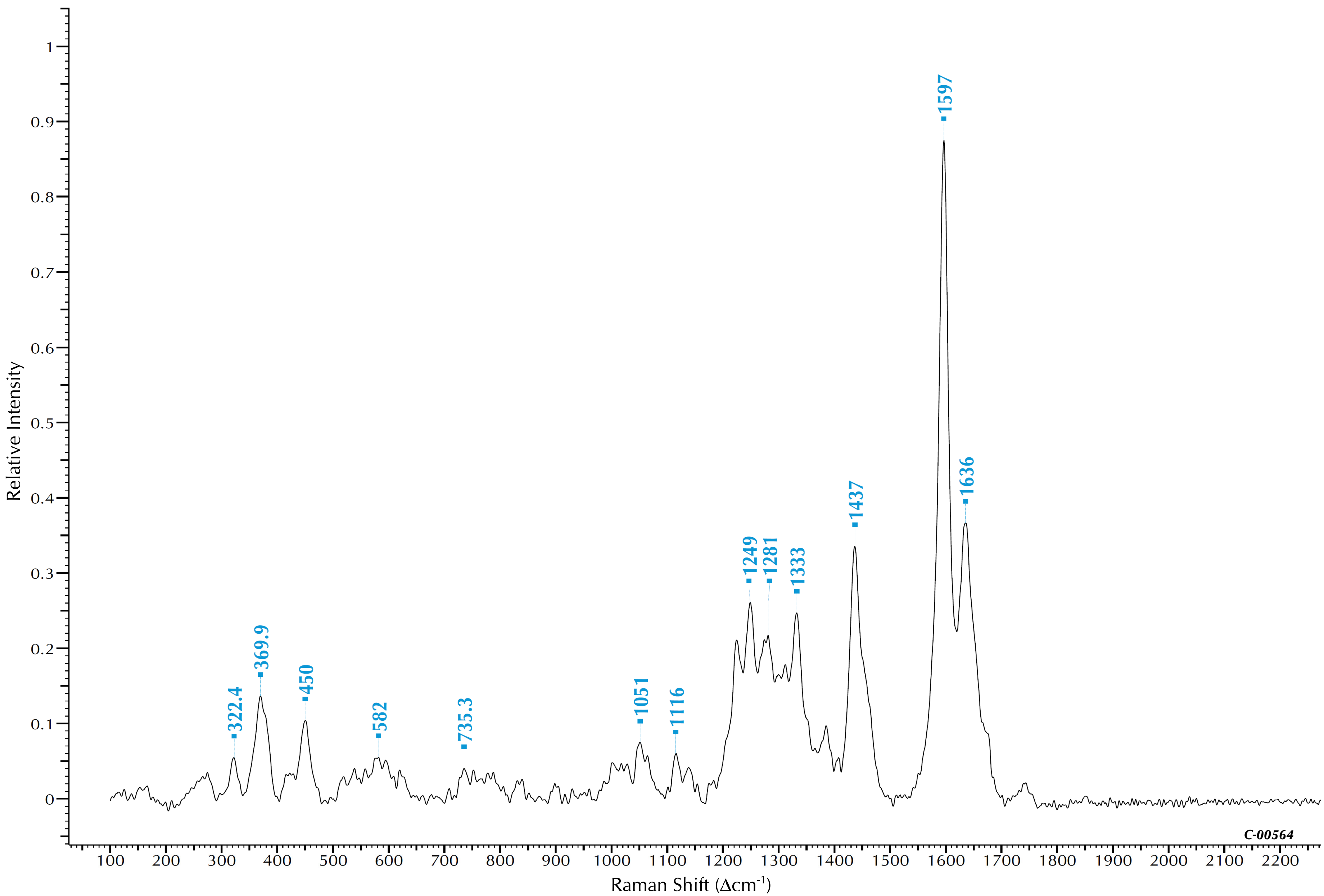
Chemical Category: Organic - Azo - Red Azo Pigment Lakes - Naphthalene Sulfonic Acid Lakes
Constitution Number: 15985:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 108



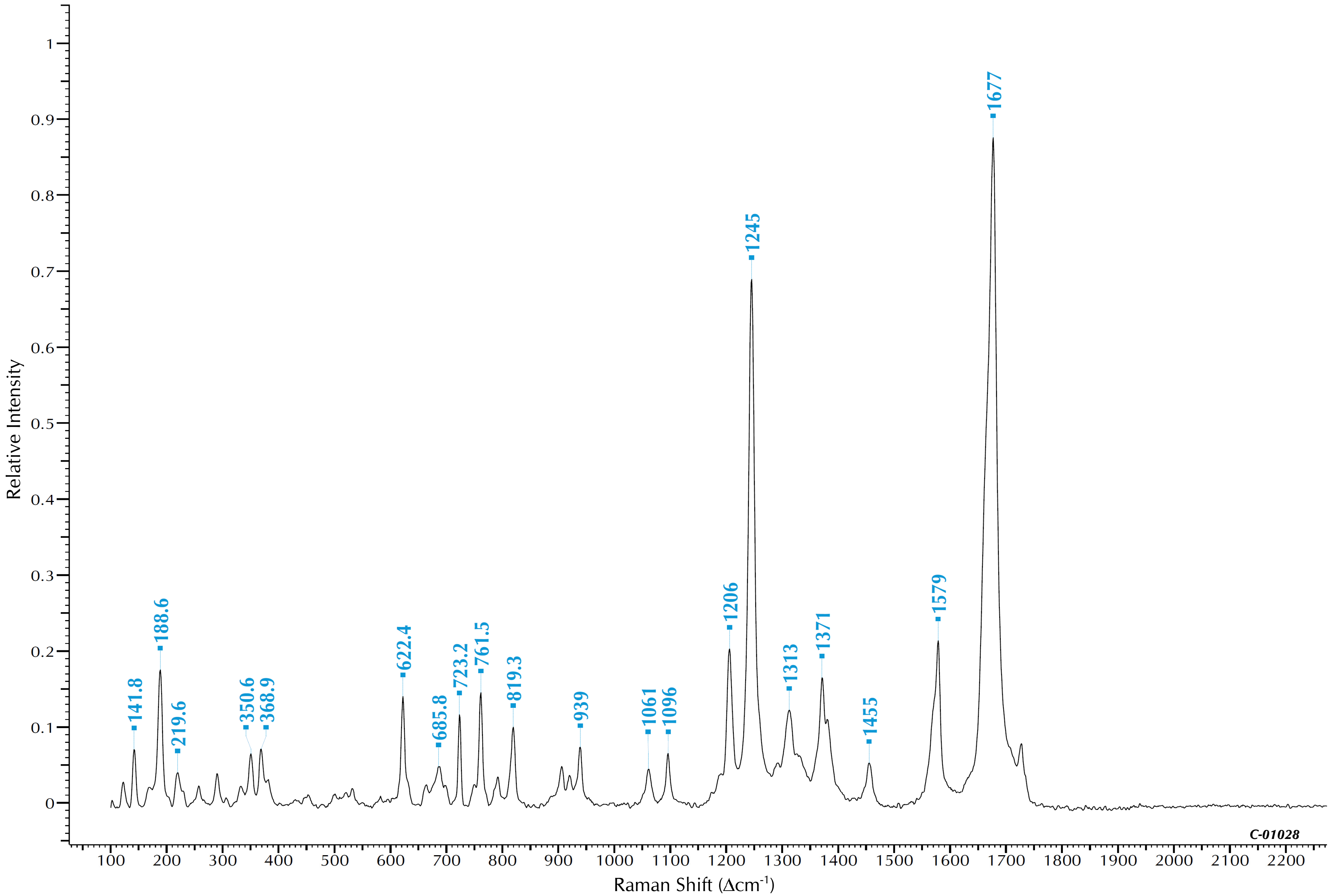
Chemical Category: Organic - Polycyclic - Heterocyclic Anthraquinone - Anthrapyrimidine
Constitution Number: 68420

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 4

Microtrace LLC

C.I. Pigment Yellow 109



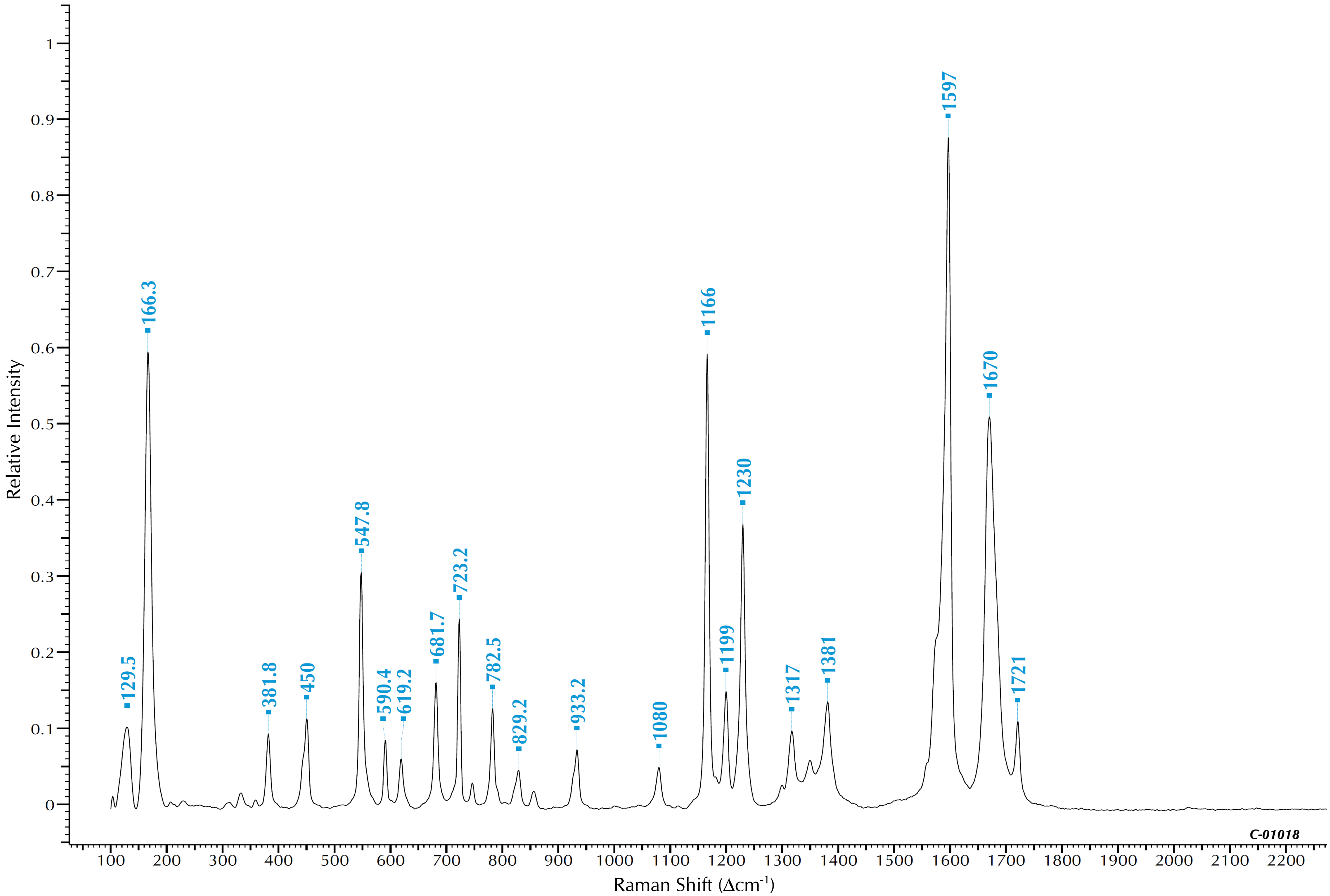
Chemical Category: Organic - Azo - Isoindolinone - Azomethine
Constitution Number: 56284

Bleaching Time (s): 60
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 110



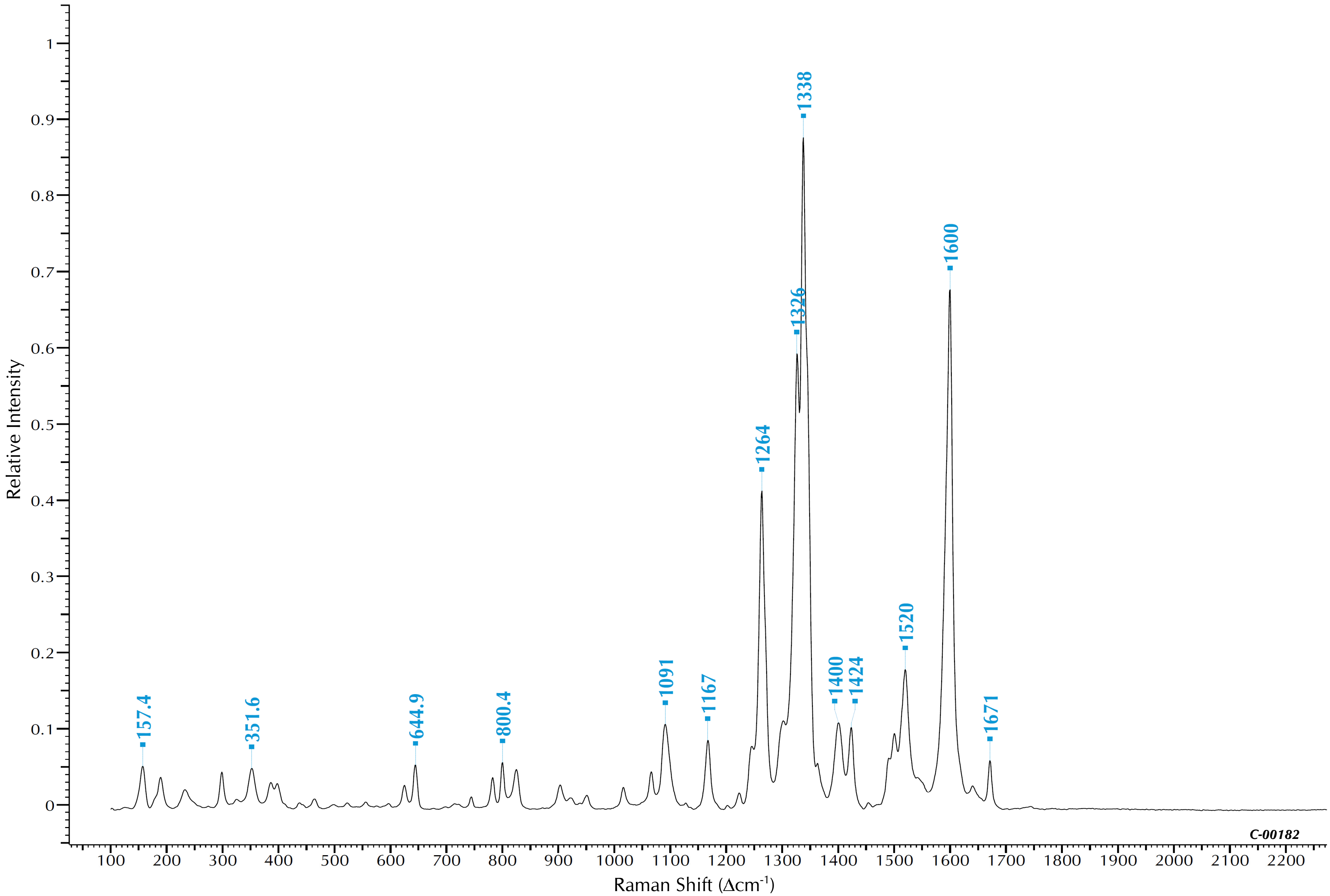
Chemical Category: Organic - Azo - Isoindolinone - Azomethine
Constitution Number: 56280

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 111



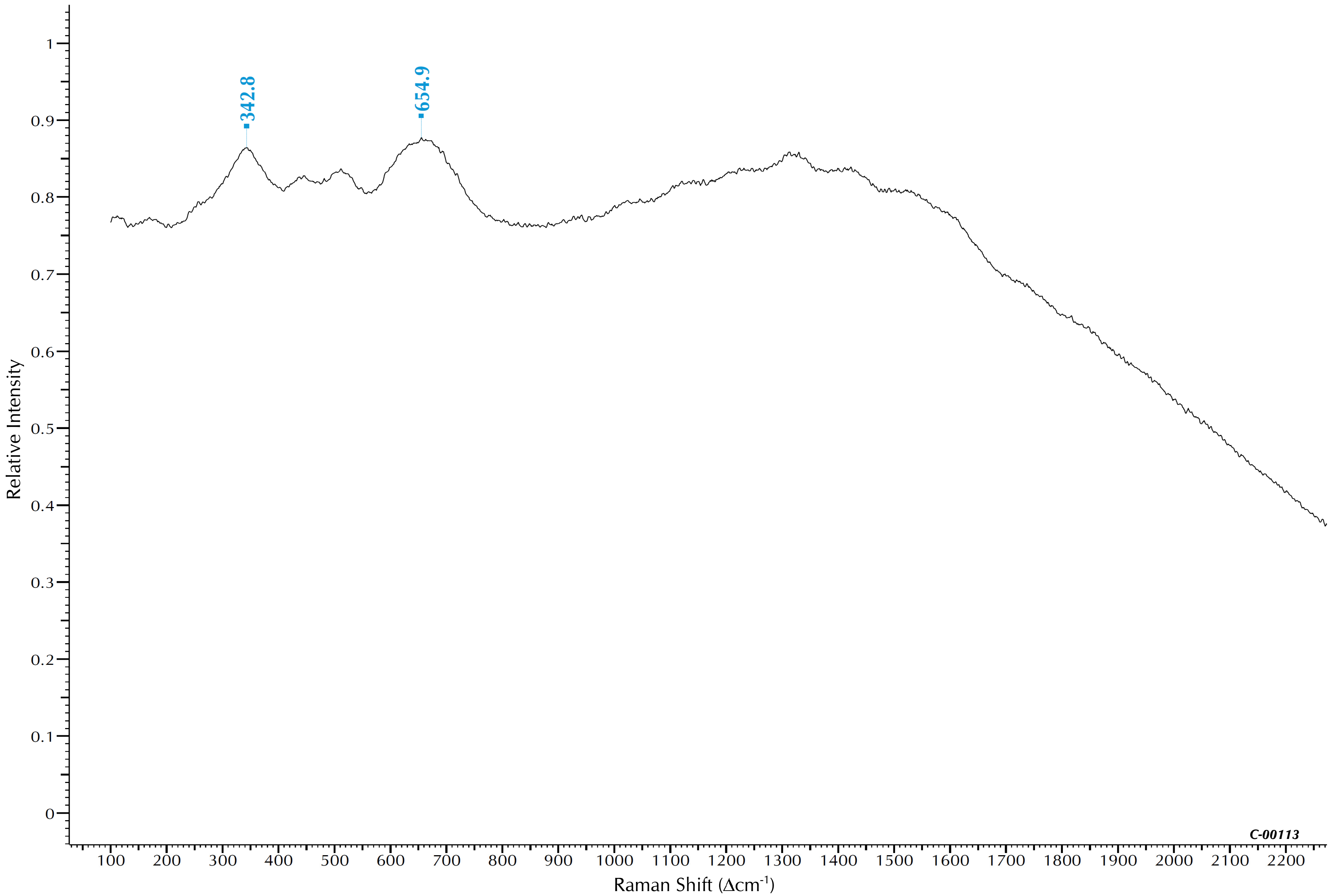
Chemical Category: Organic - Azo - Monoazo - General
Constitution Number: 11745

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 119



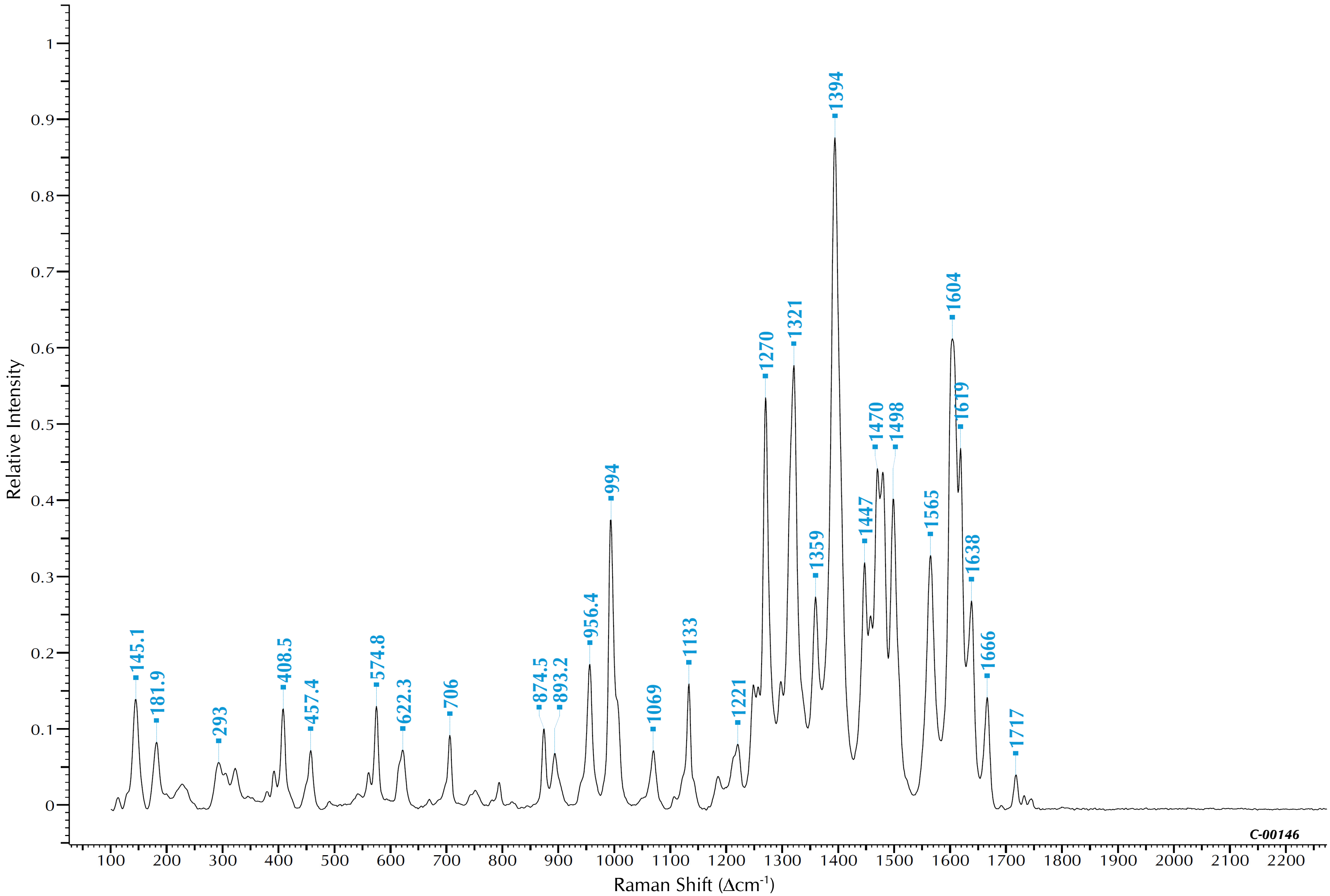
Chemical Category: Inorganic - Oxide
Constitution Number: 77496

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 120



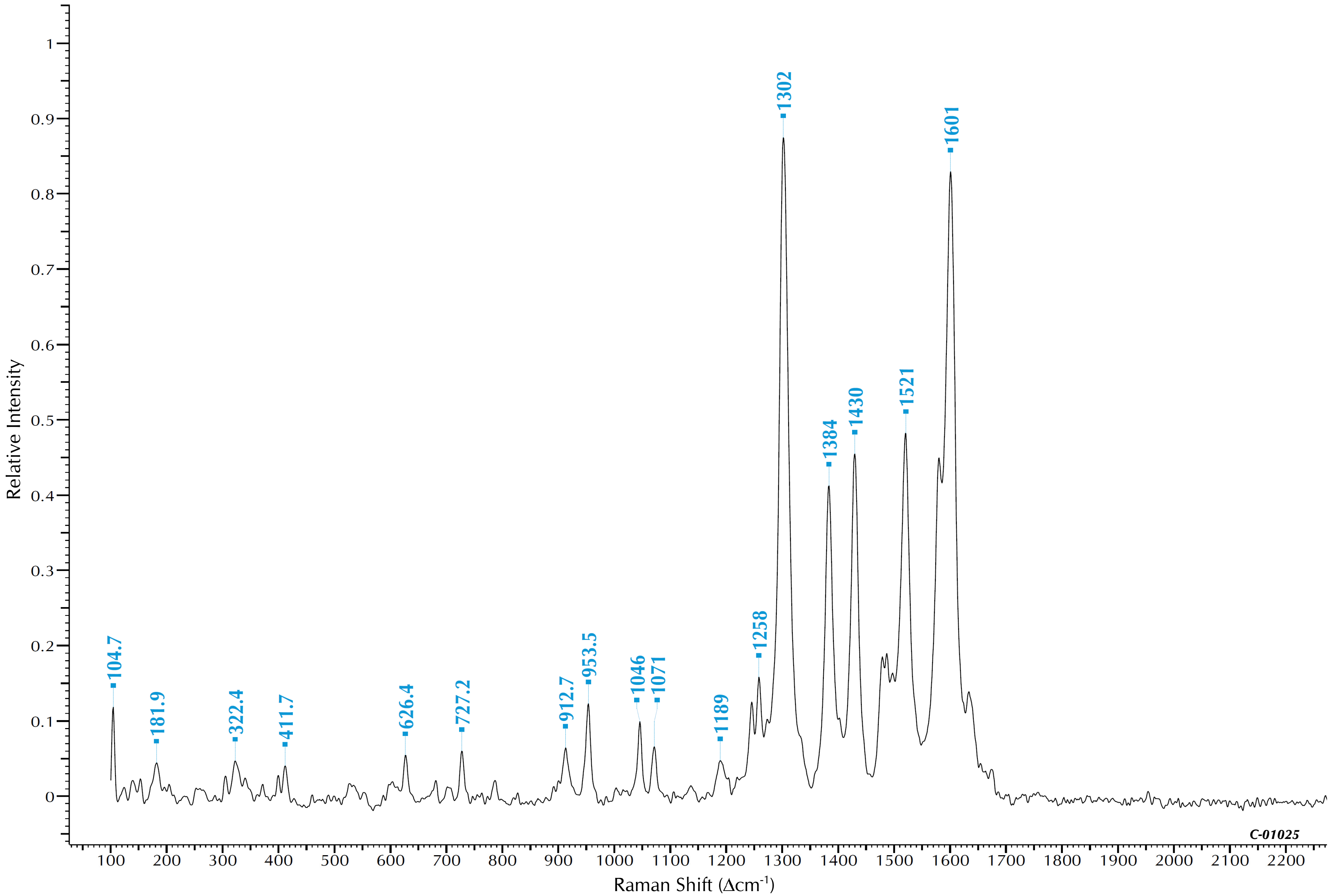
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 11783

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 128



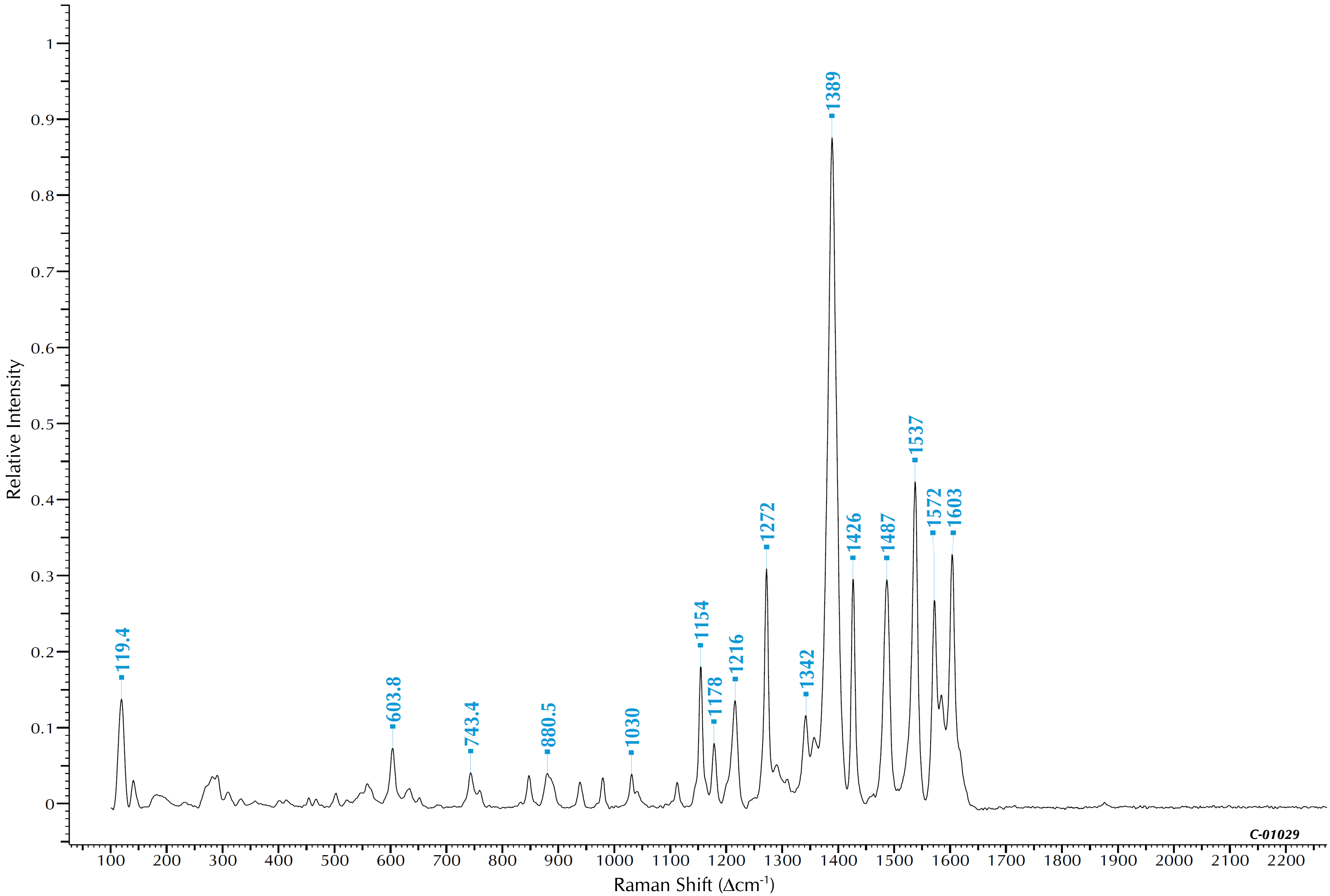
Chemical Category: Organic - Azo - Disazo Condensation
Constitution Number: 20037

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 129



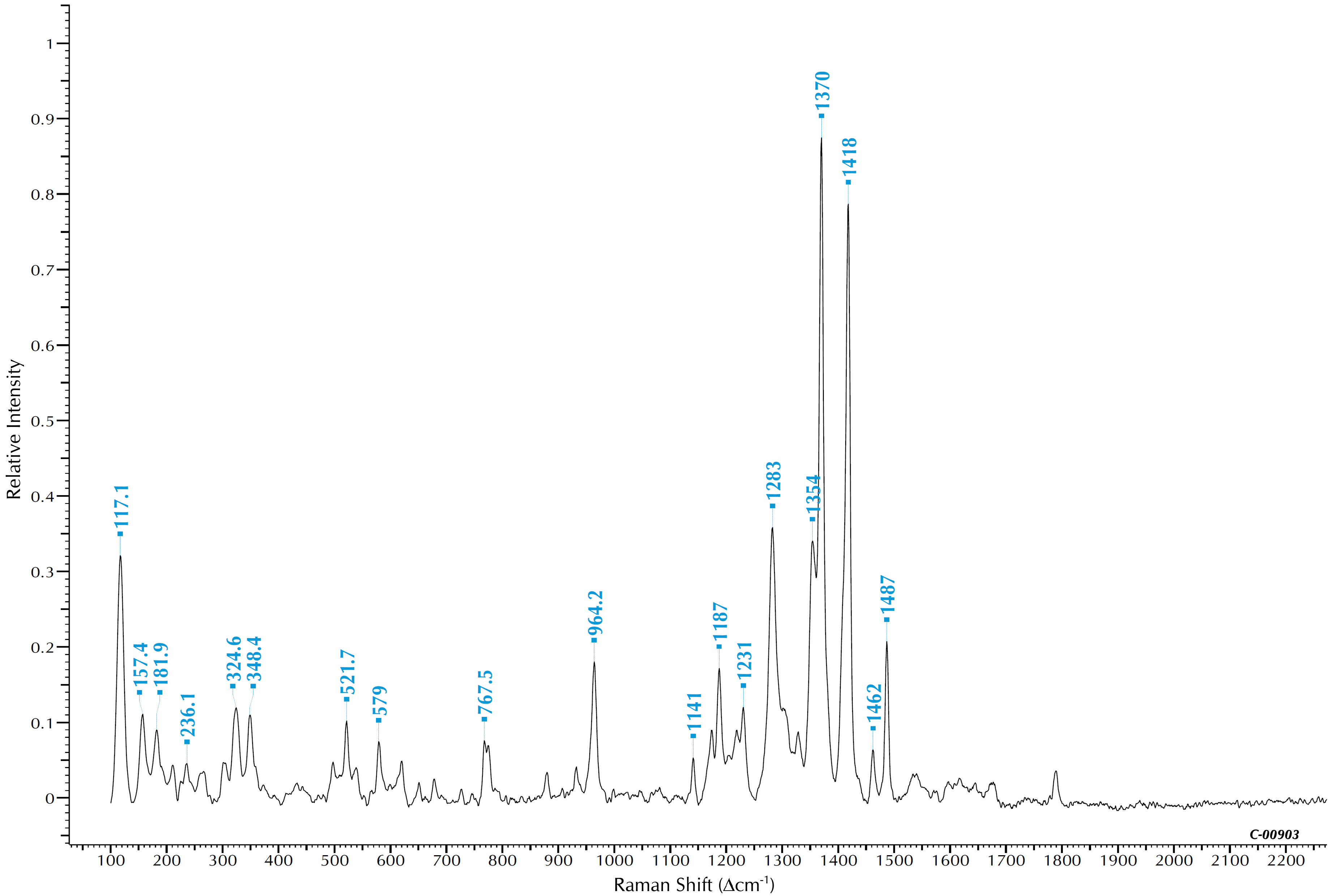
Chemical Category: Organic - Azo - Metal Complex - Azomethine
Constitution Number: 48042

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 138



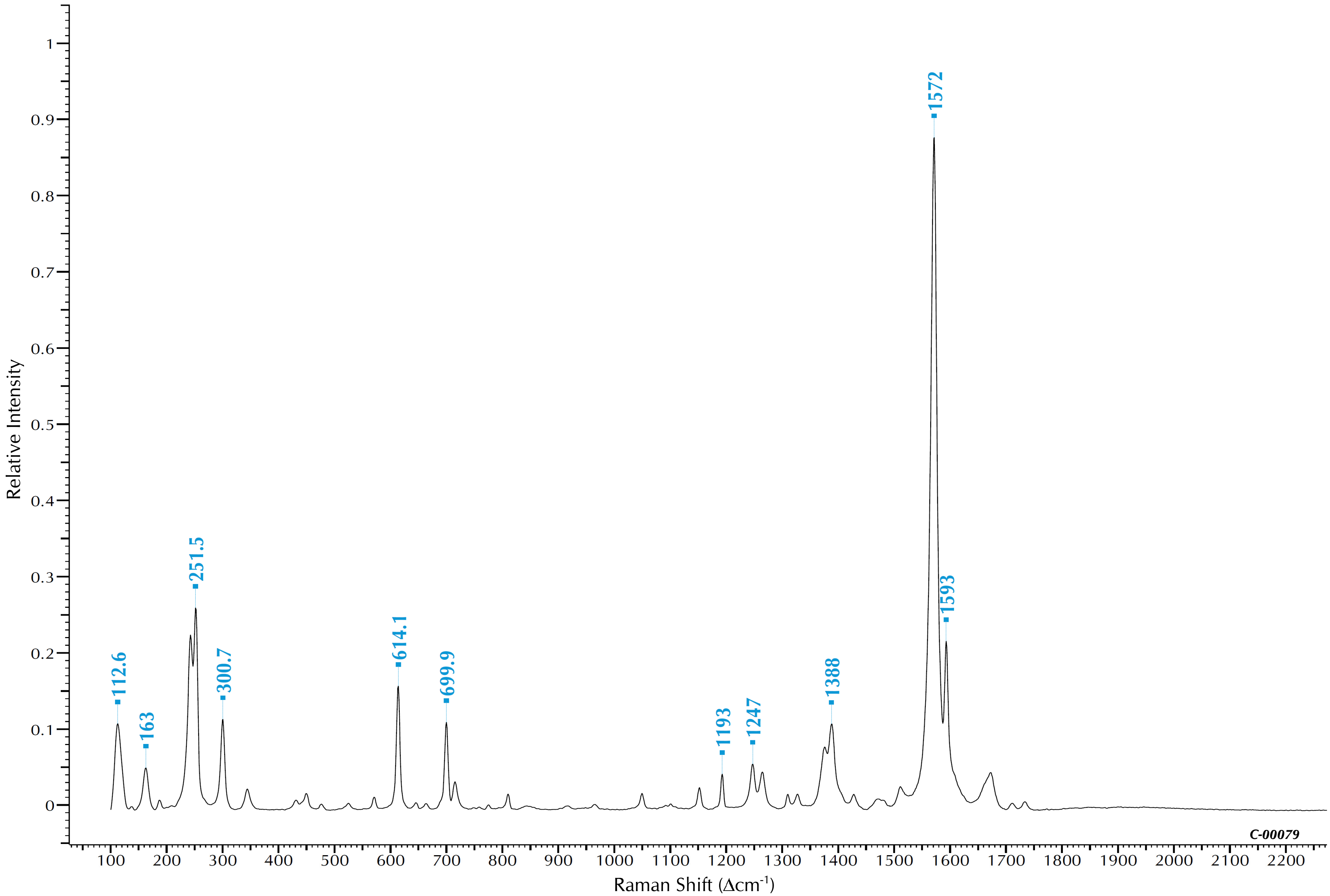
Chemical Category: Organic - Polycyclic - Quinophthalone
Constitution Number: 56300

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 139



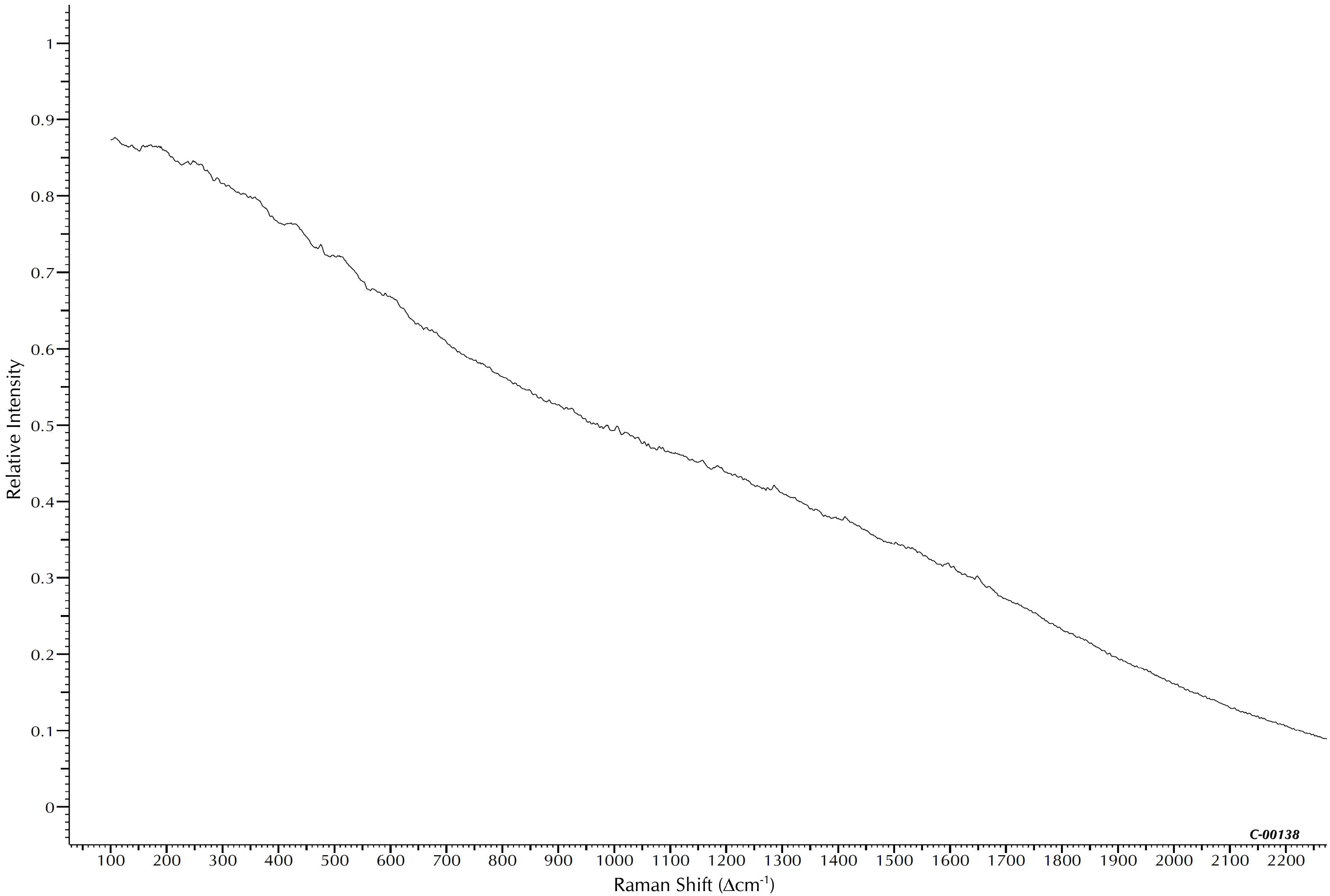
Chemical Category: Organic - Azo - Isoindoline - Methine
Constitution Number: 56298

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 147

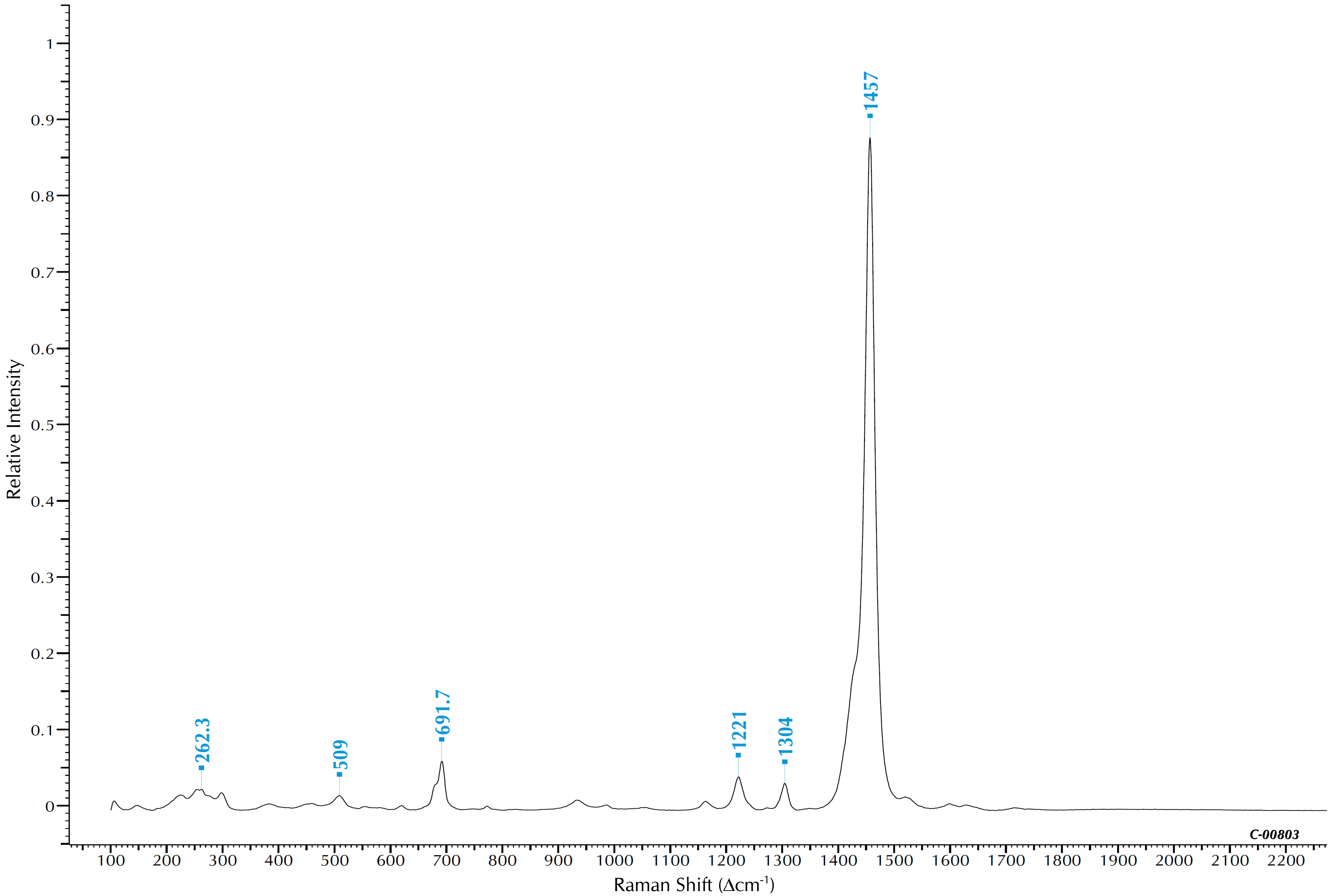


Chemical Category: Organic - Polycyclic - Aminoanthraquinone
Constitution Number: 60645

Bleaching Time (s): 360
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.39
Quality Index 3

C.I. Pigment Yellow 150



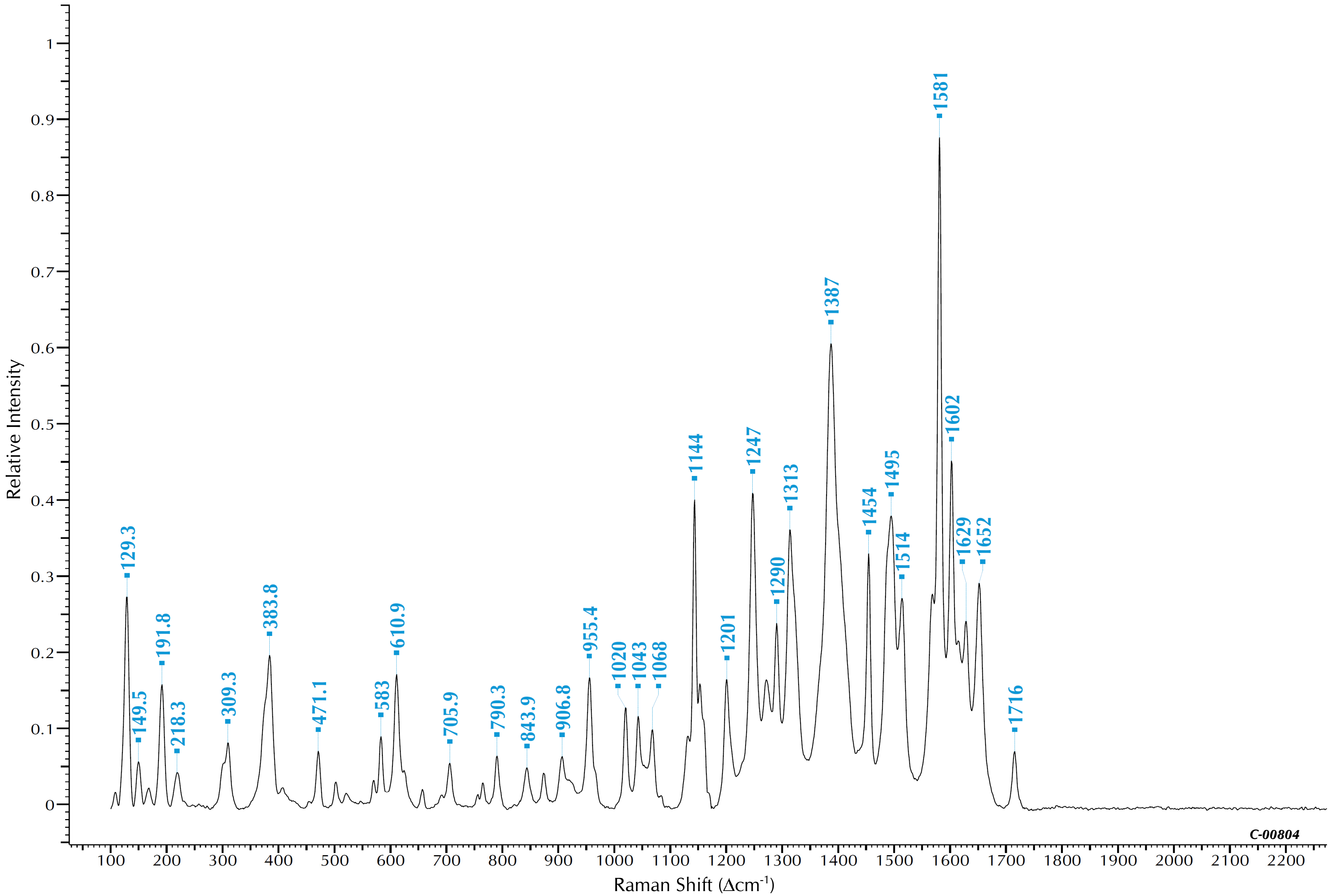
Chemical Category: Organic - Azo - Metal Complex - Azo
Constitution Number: 12764

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 2

Microtrace LLC

C.I. Pigment Yellow 151



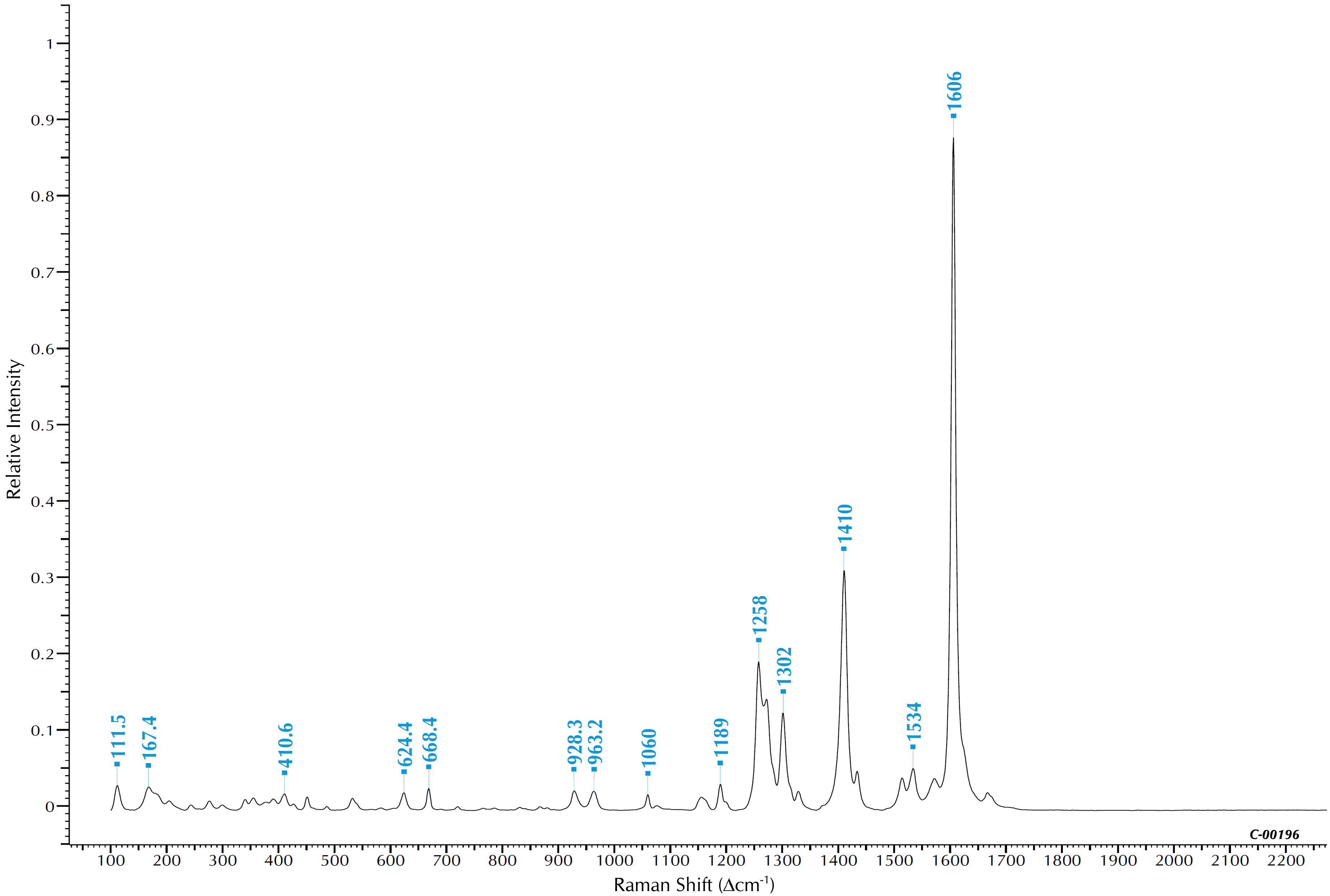
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 13980

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 152



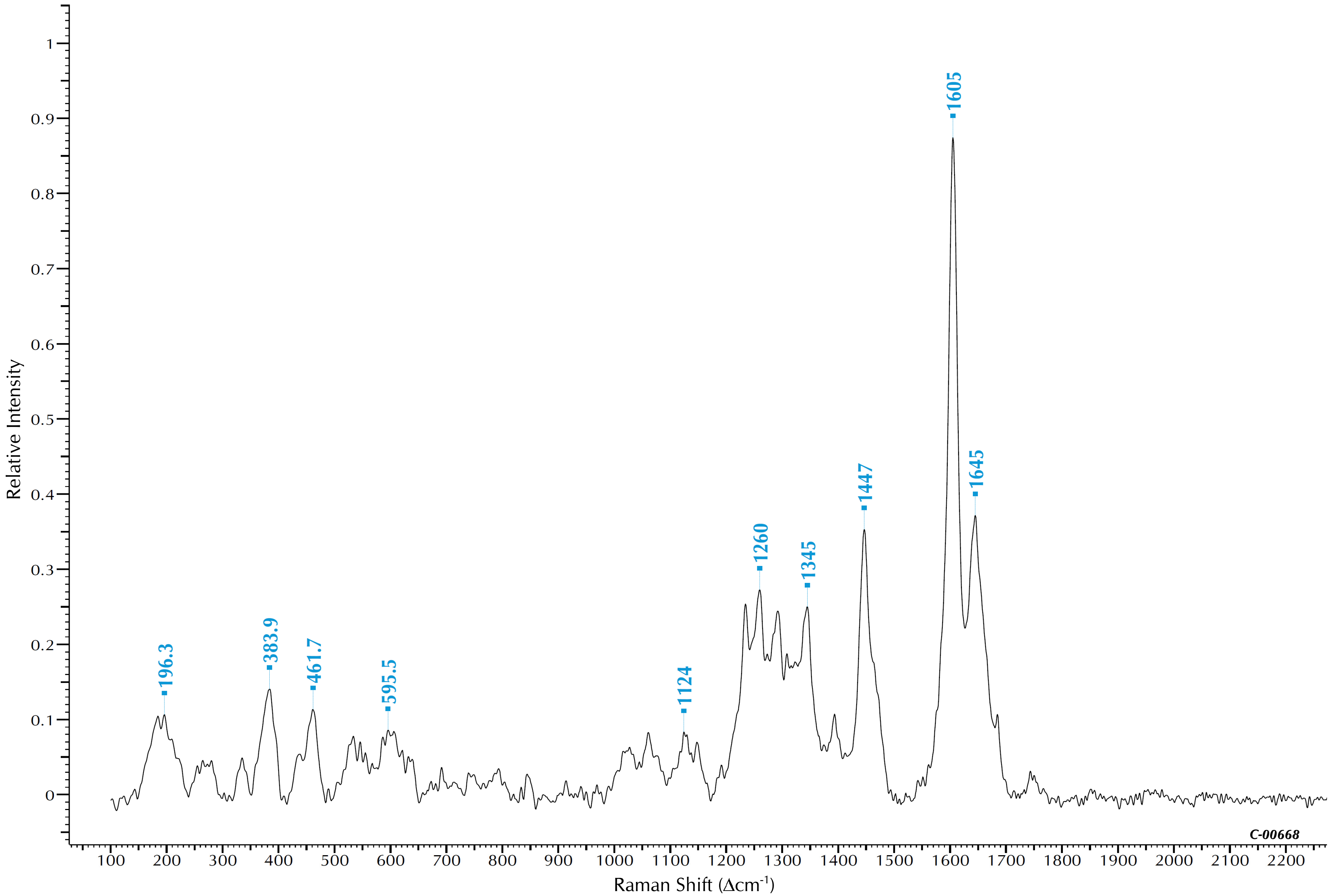
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21111

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 153



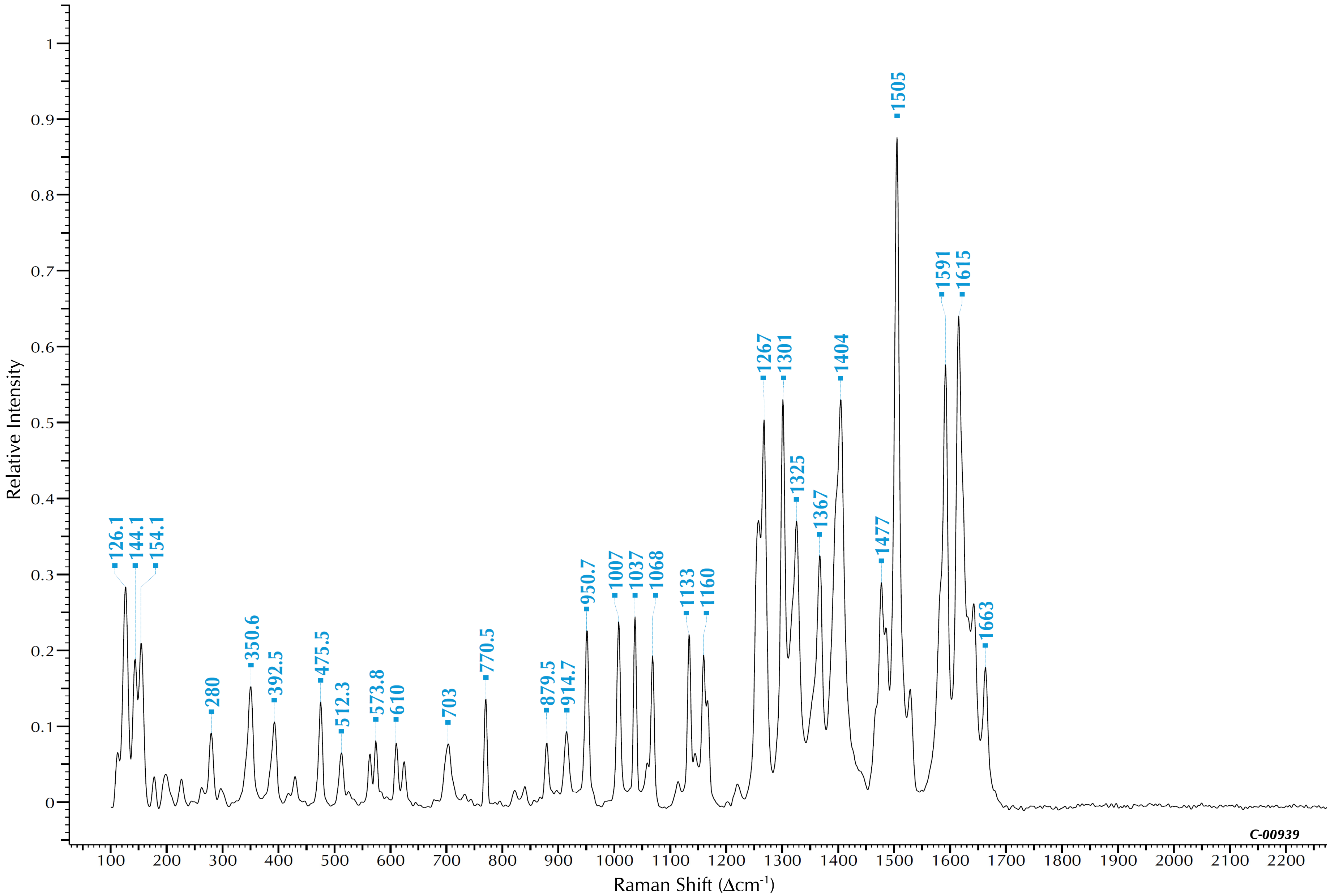
Chemical Category: Organic - Azo - Metal Complex - Azomethine
Constitution Number: 48545

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 4

Microtrace LLC

C.I. Pigment Yellow 154



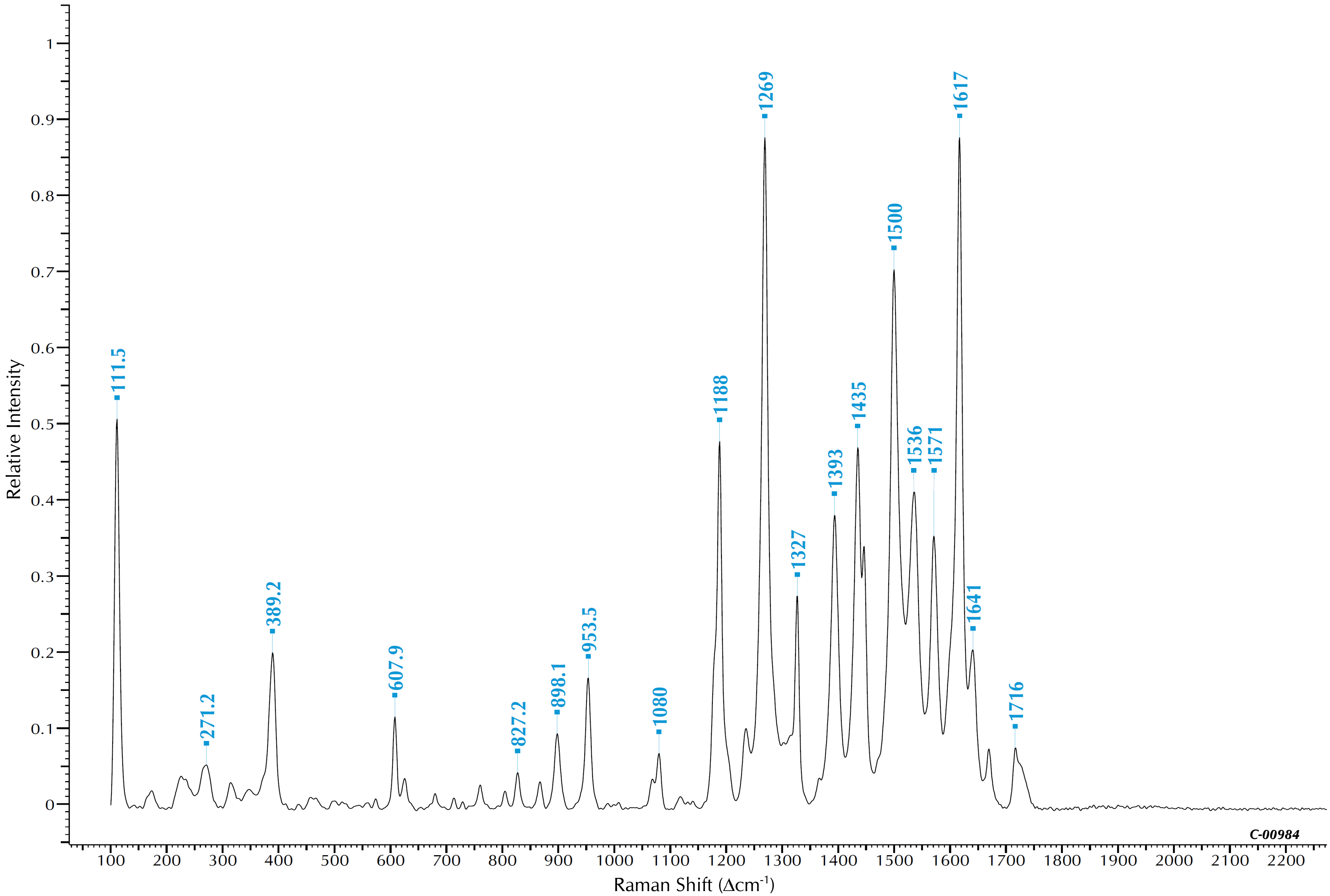
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 11781

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 155



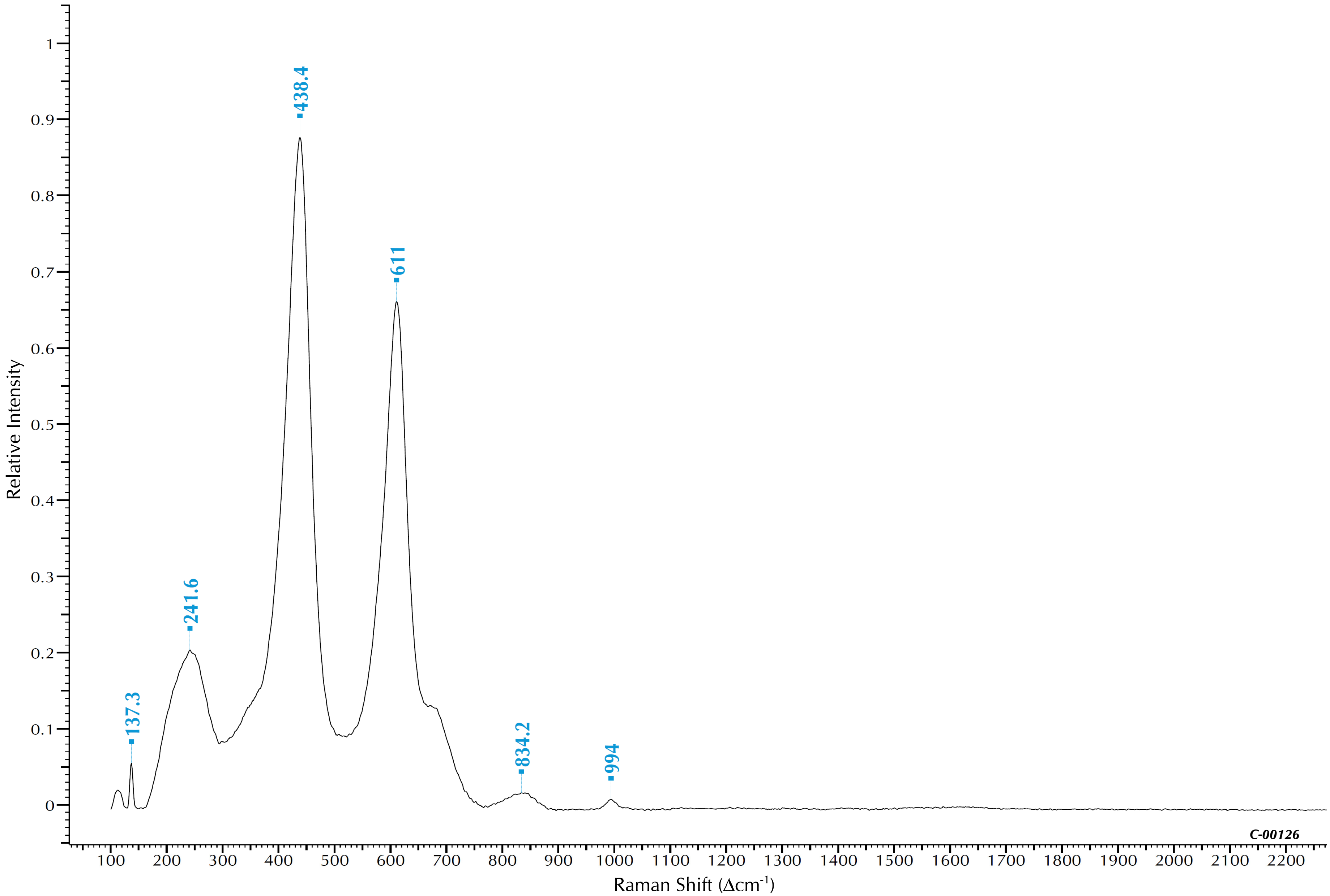
Chemical Category: Organic - Azo - Disazo - Bisacetoacetarylide
Constitution Number: 200310

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 161



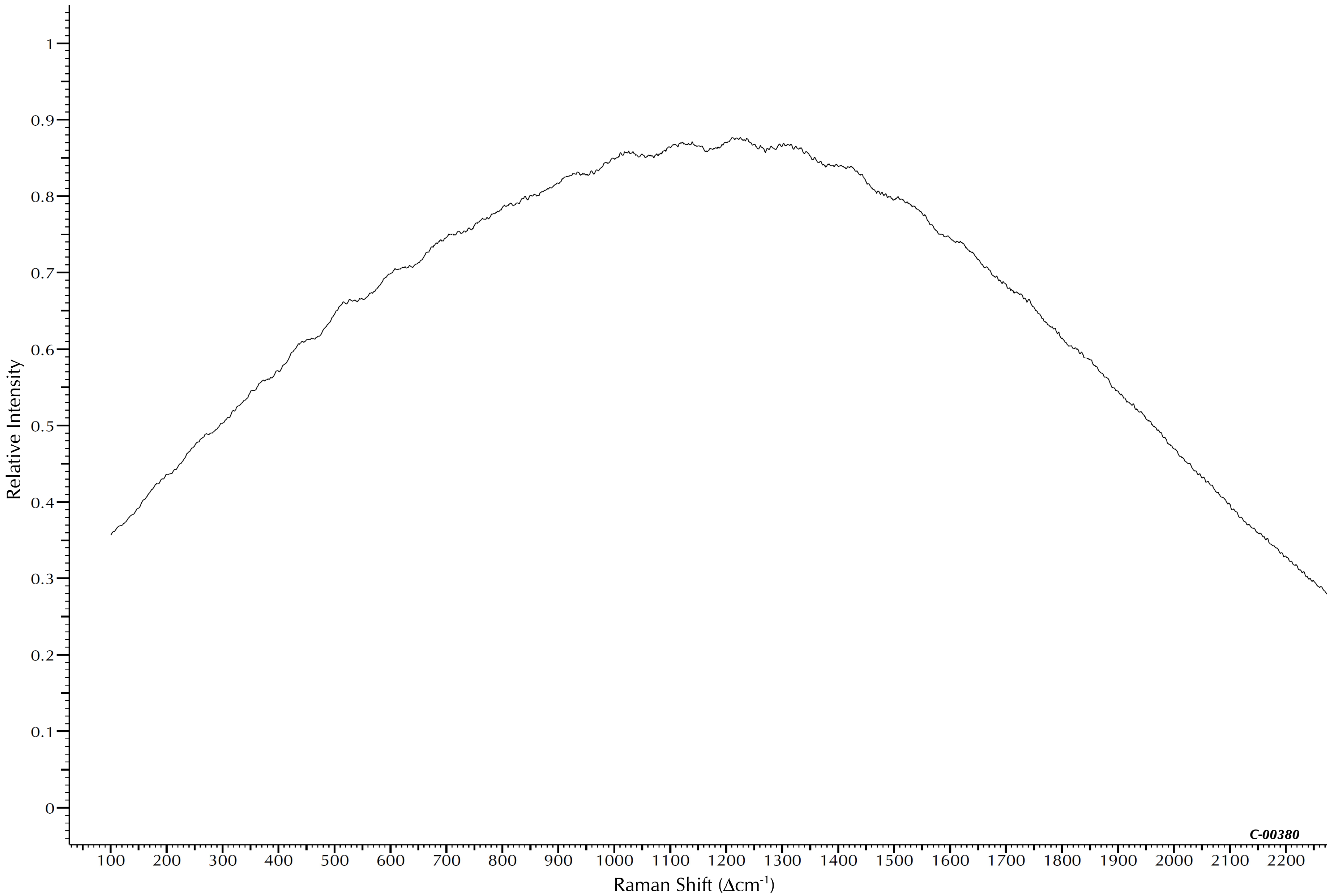
Chemical Category: Inorganic - Titanate
Constitution Number: 77895

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 162



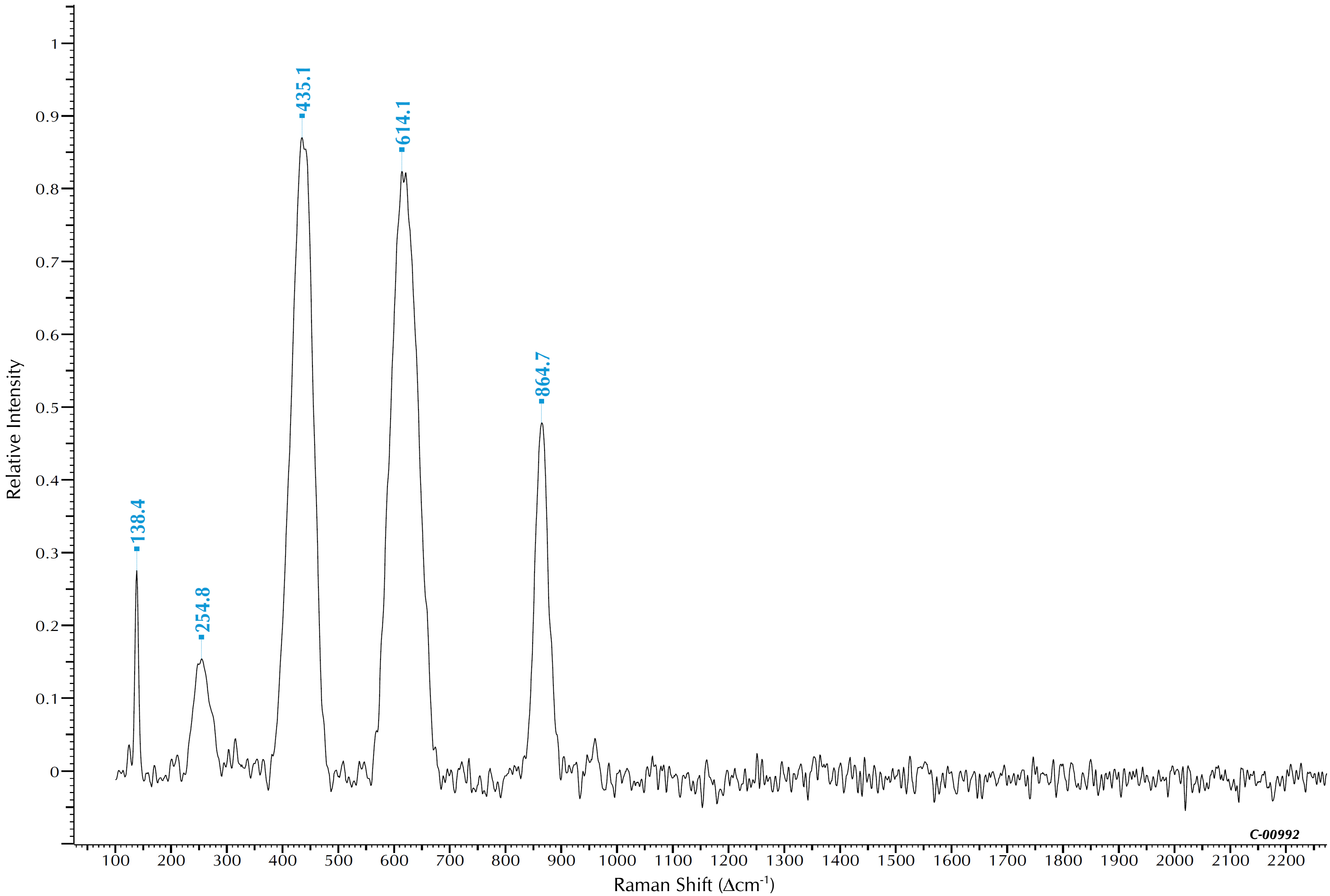
Chemical Category: Inorganic - Oxide
Constitution Number: 77896

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.01
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 163



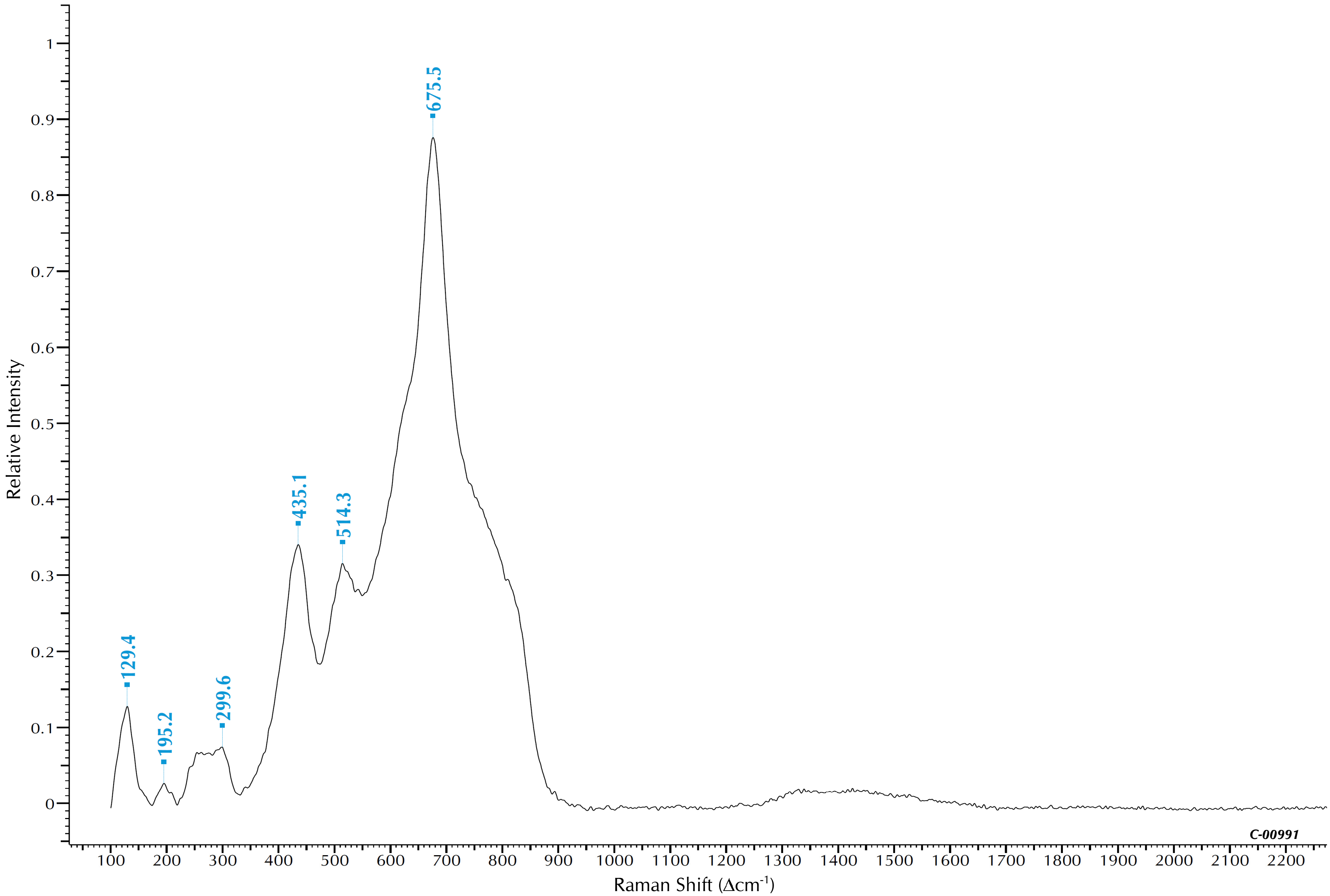
Chemical Category: Inorganic - Titanate
Constitution Number: 77897

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 164



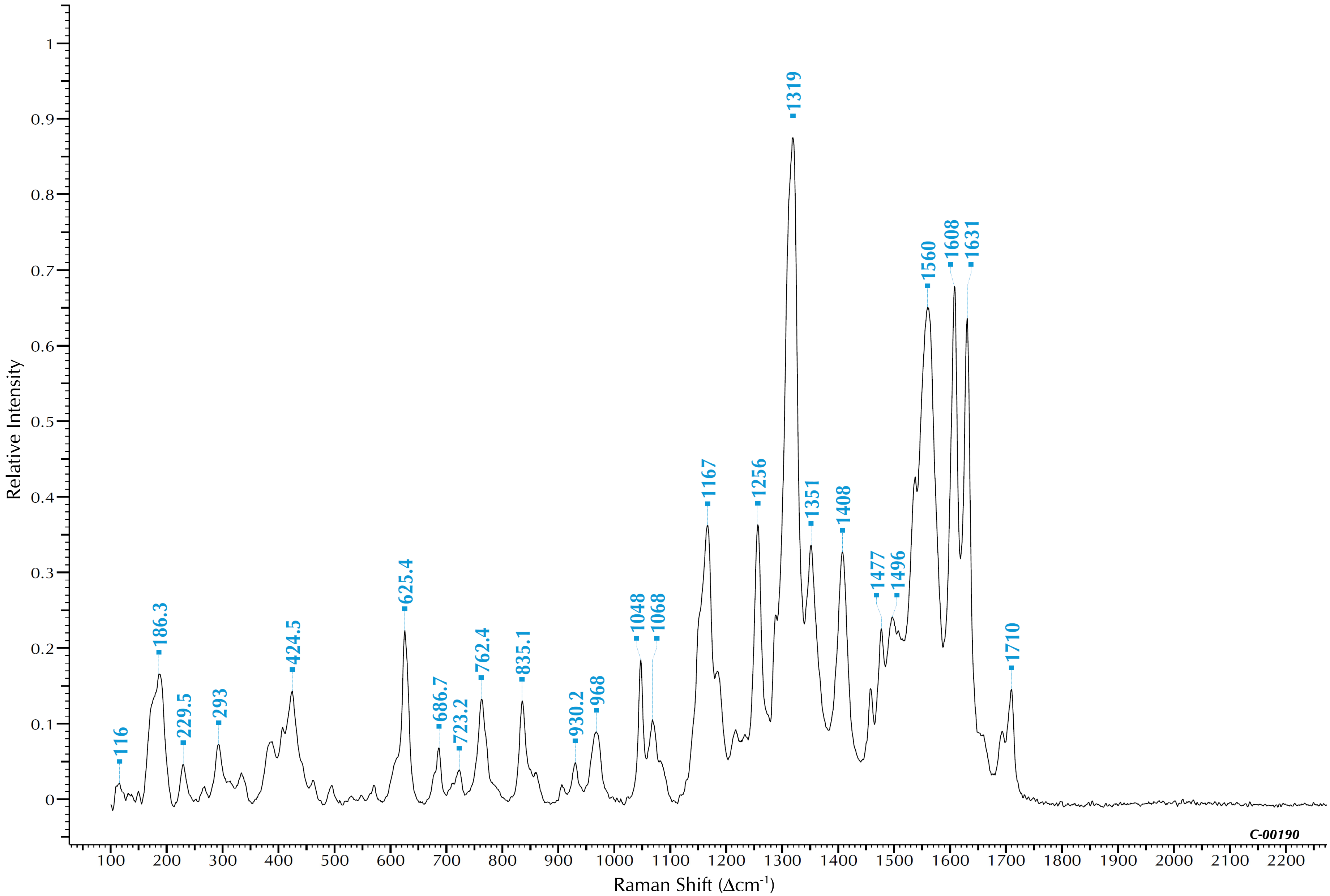
Chemical Category: Inorganic - Oxide
Constitution Number: 77899

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 168



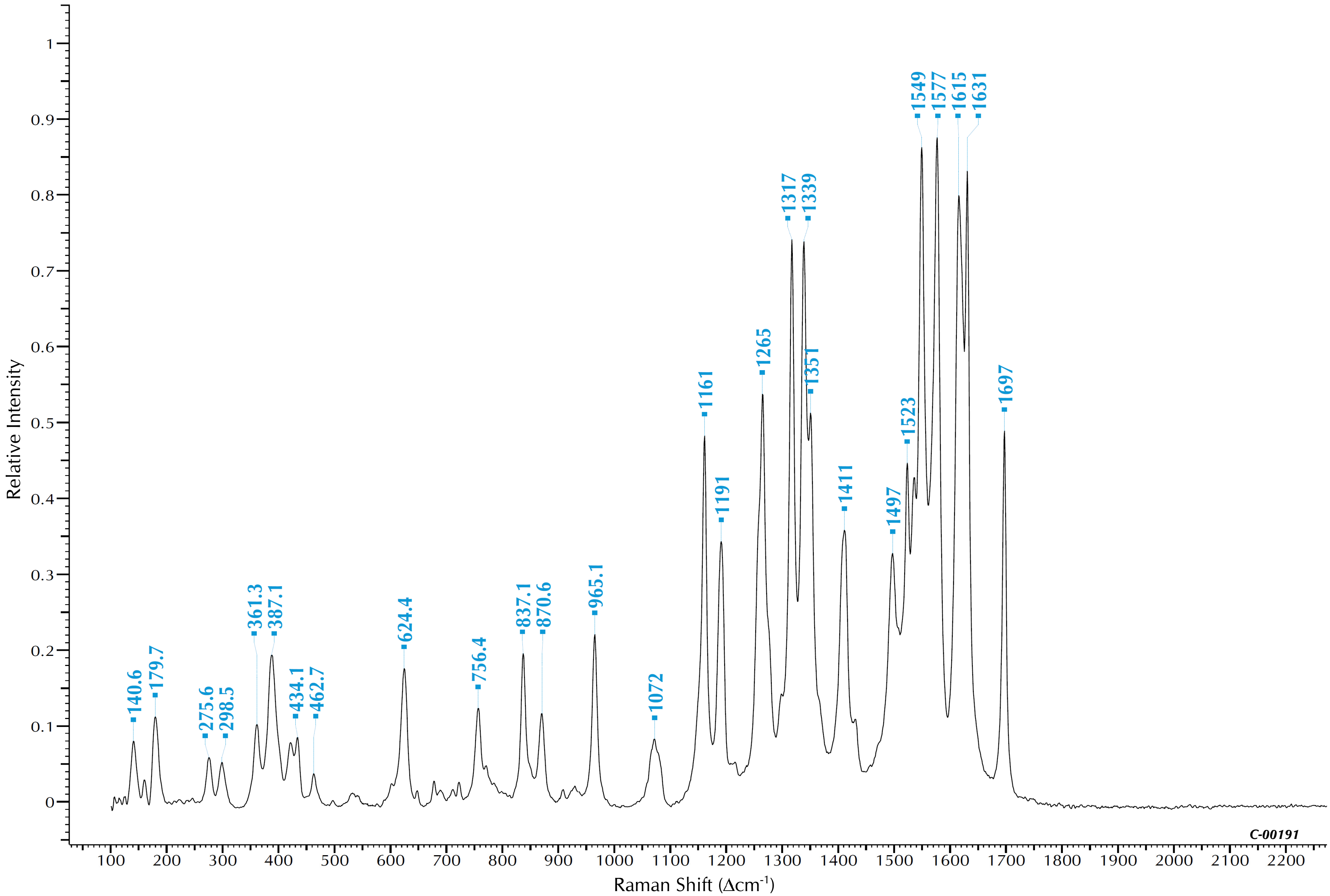
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 13960

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 169



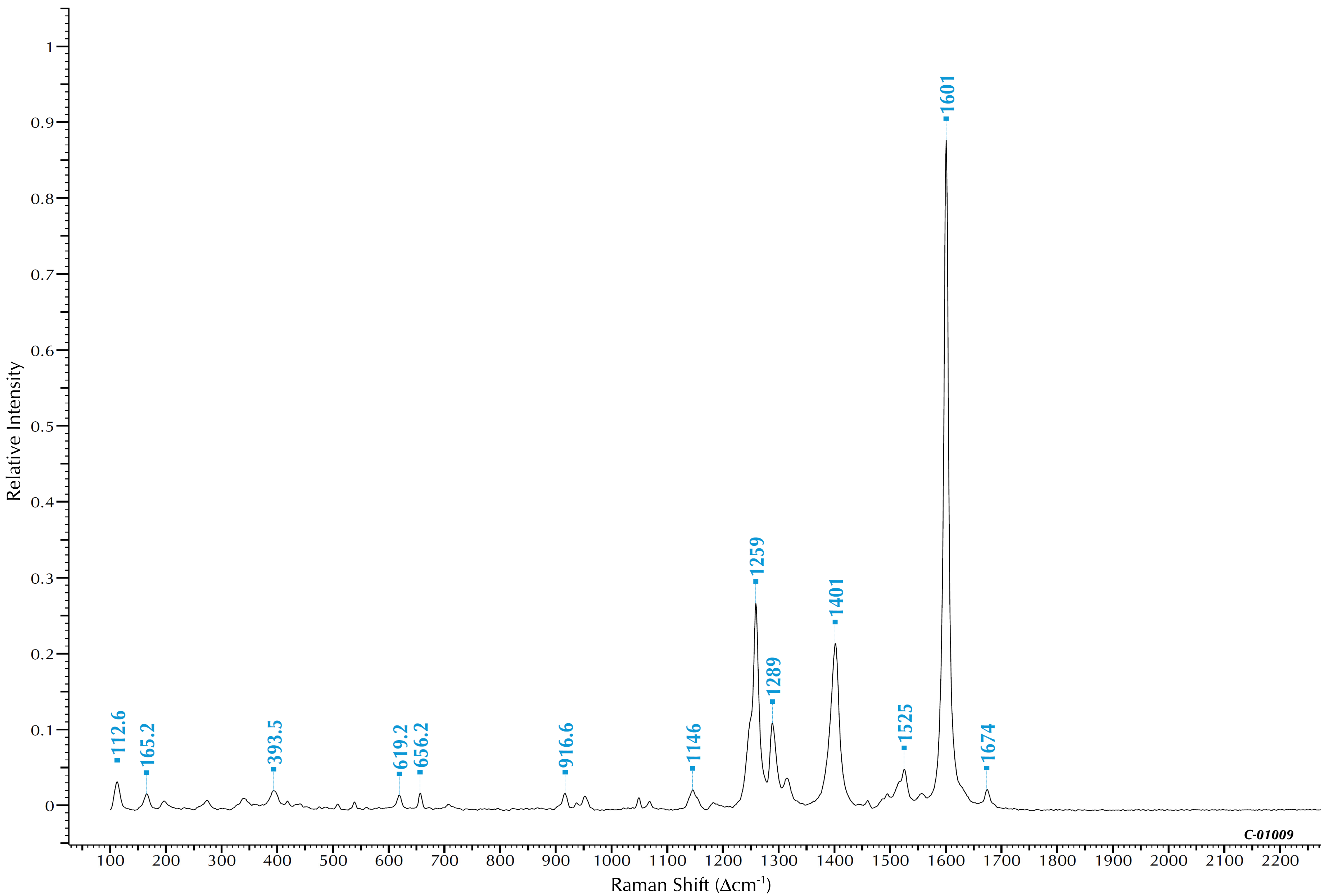
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 13955

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 9.26
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 170



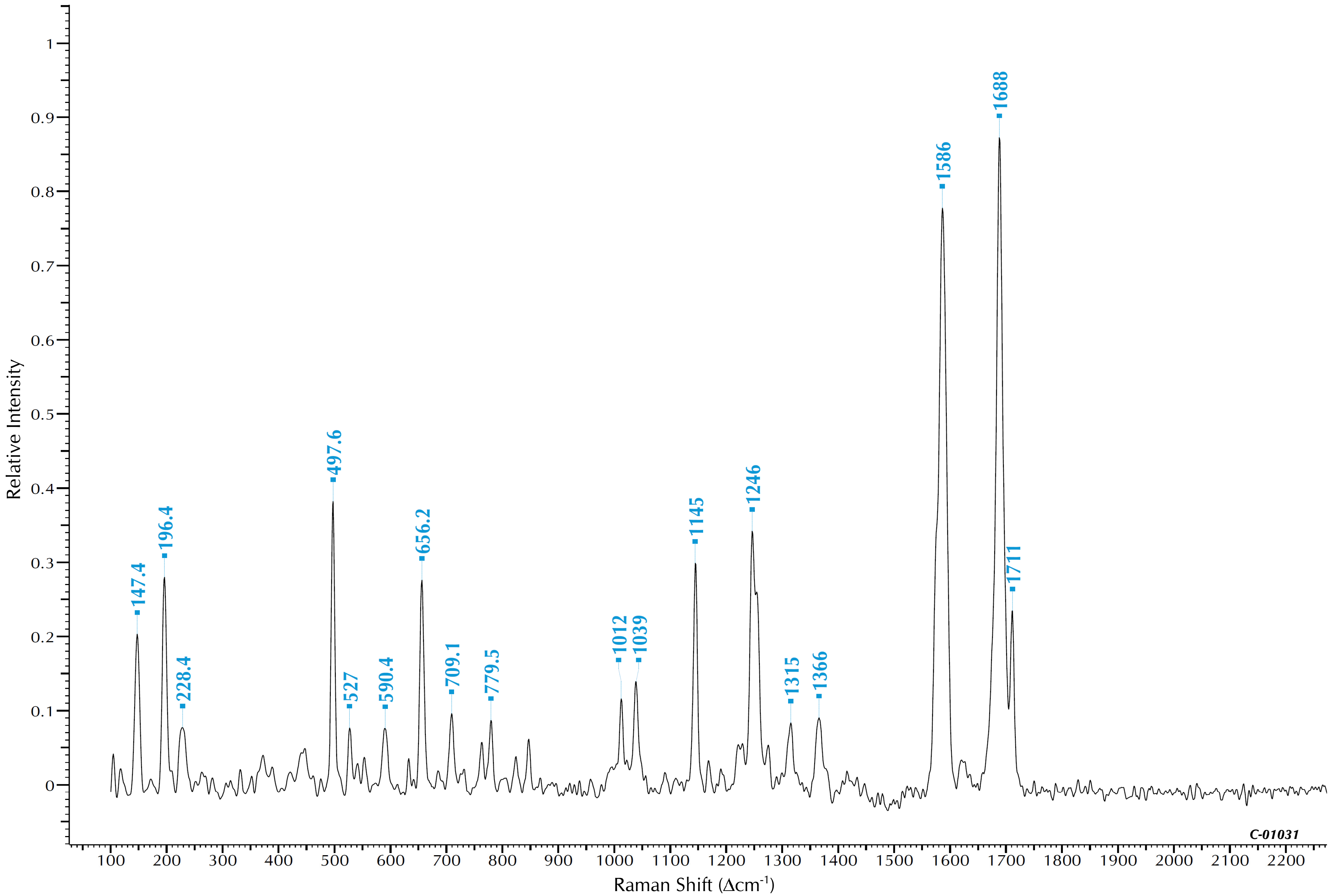
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21104

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 173



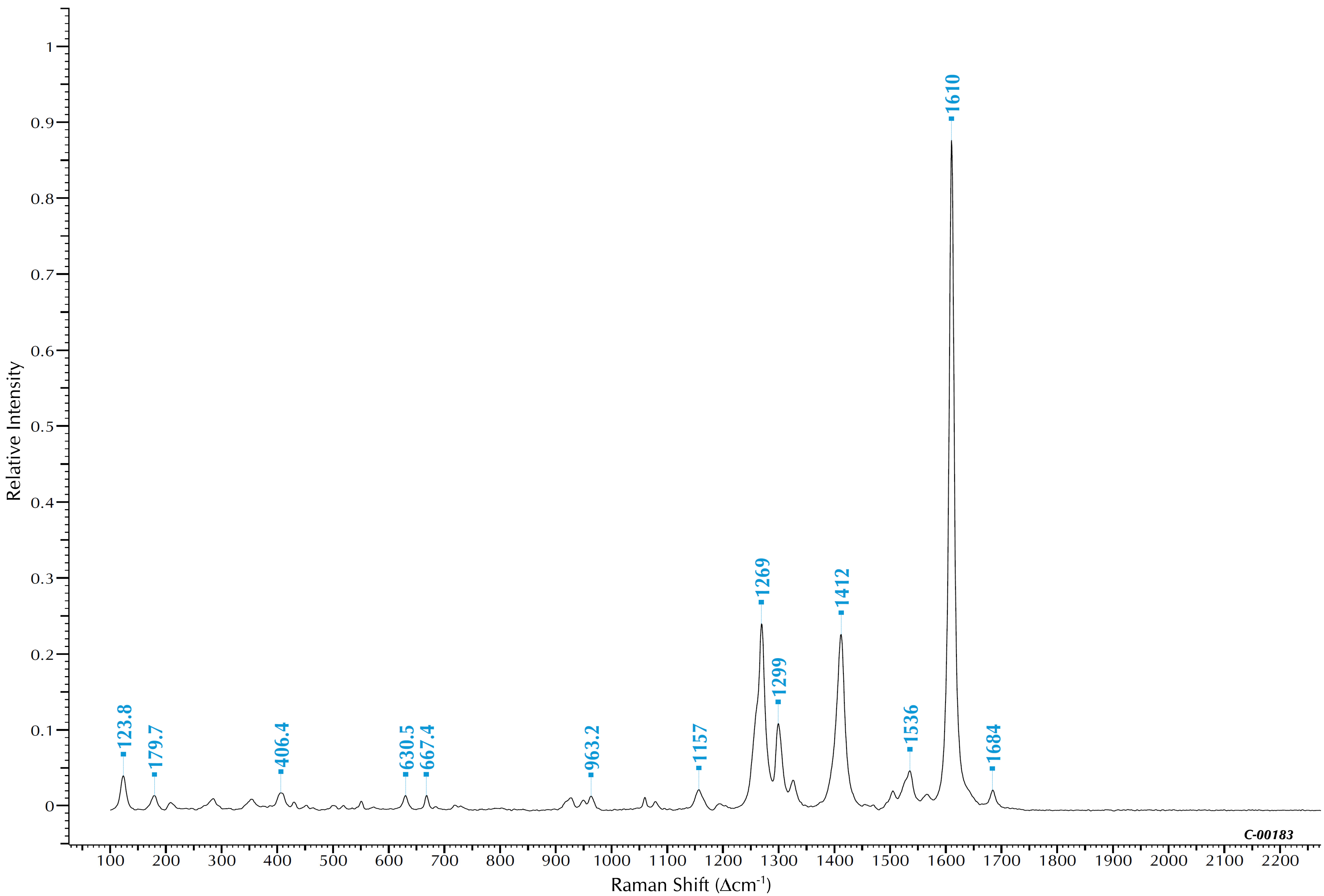
Chemical Category: Organic - Azo - Isoindolinone
Constitution Number: 561600

Bleaching Time (s): 180
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 174



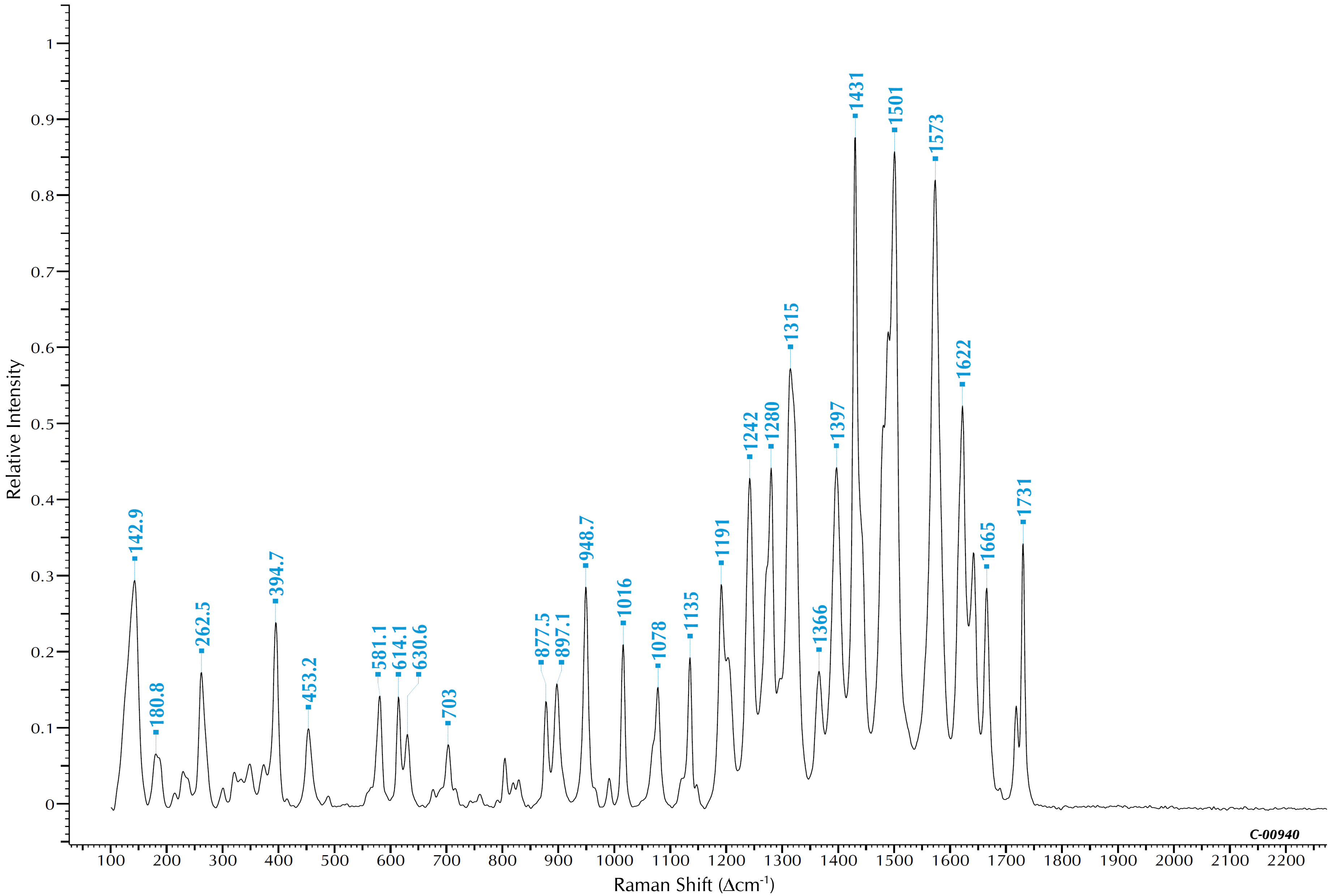
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21098

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 175



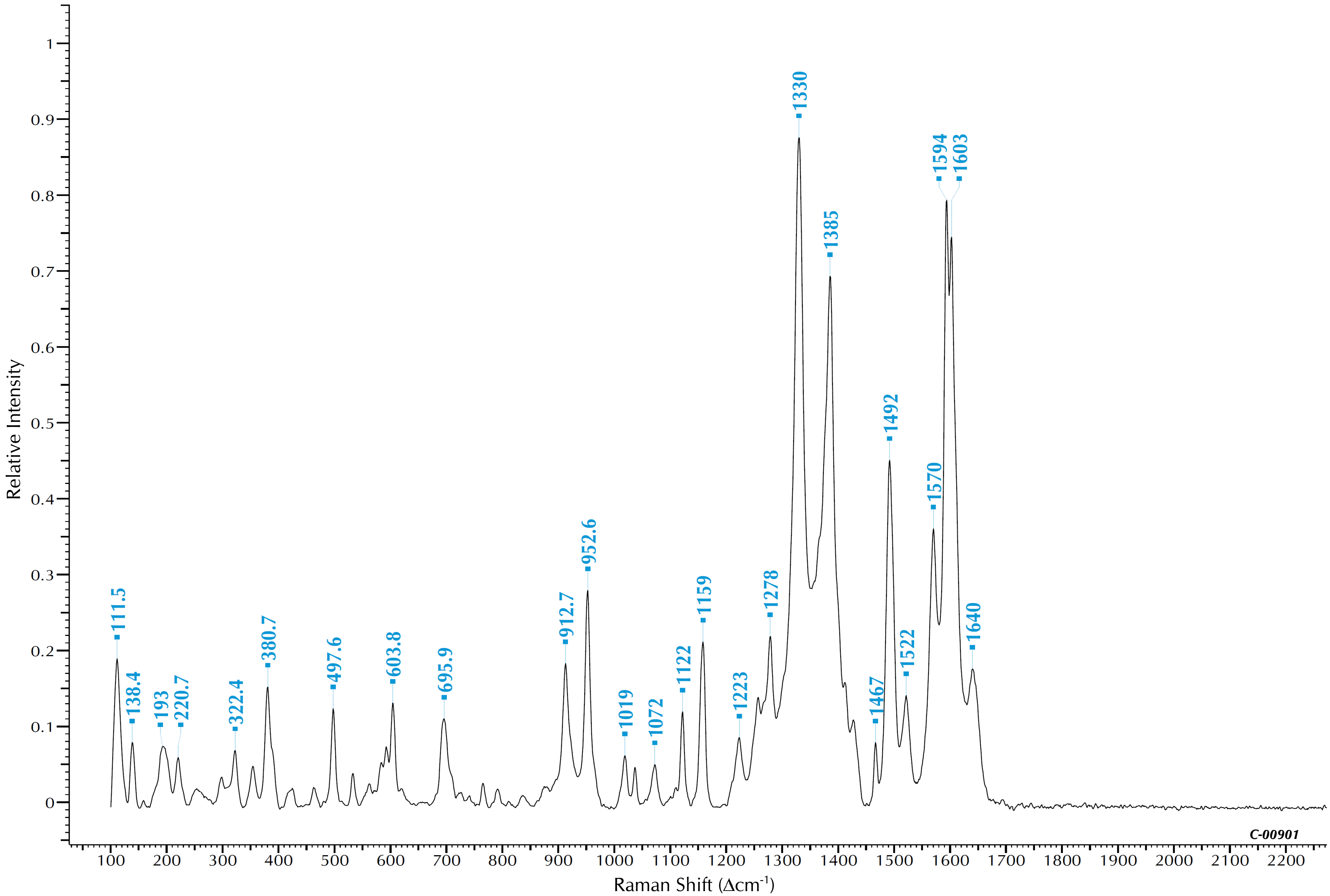
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 11784

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 180



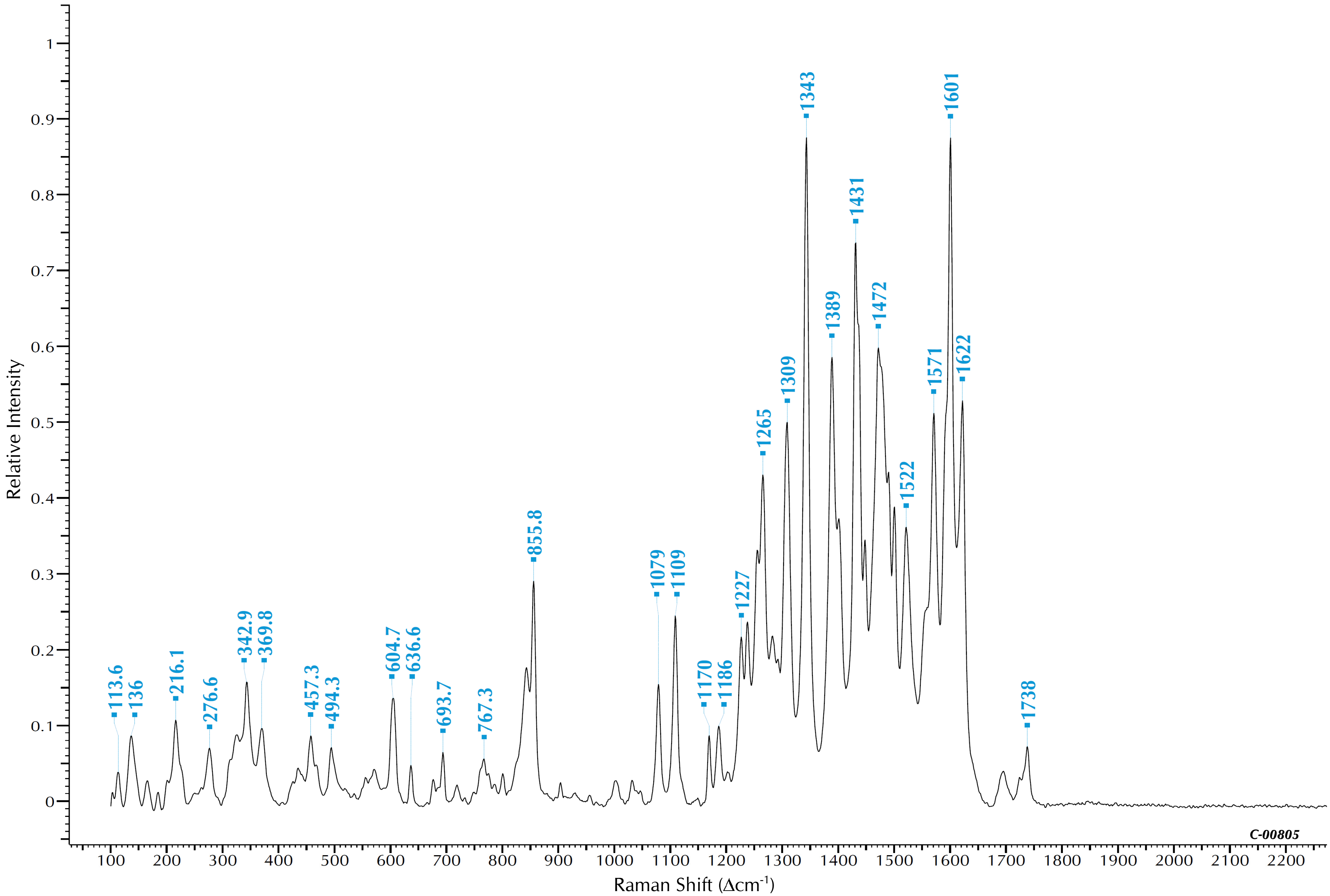
Chemical Category: Organic - Azo - Benzimidazolone - Group 1 (orange/yellow)
Constitution Number: 21290

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 3

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 182



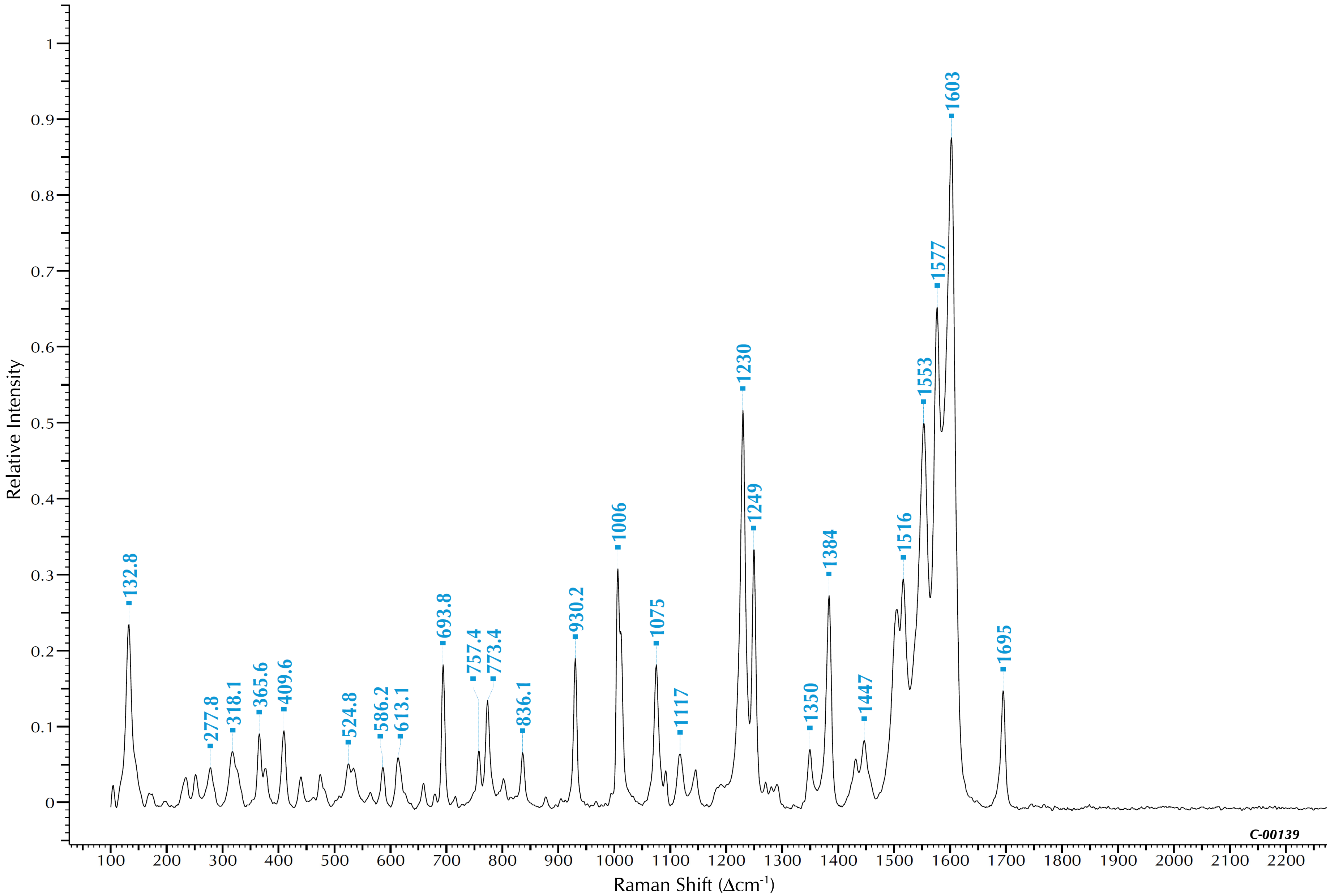
Chemical Category: Organic - Other
Constitution Number: 128300

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 183



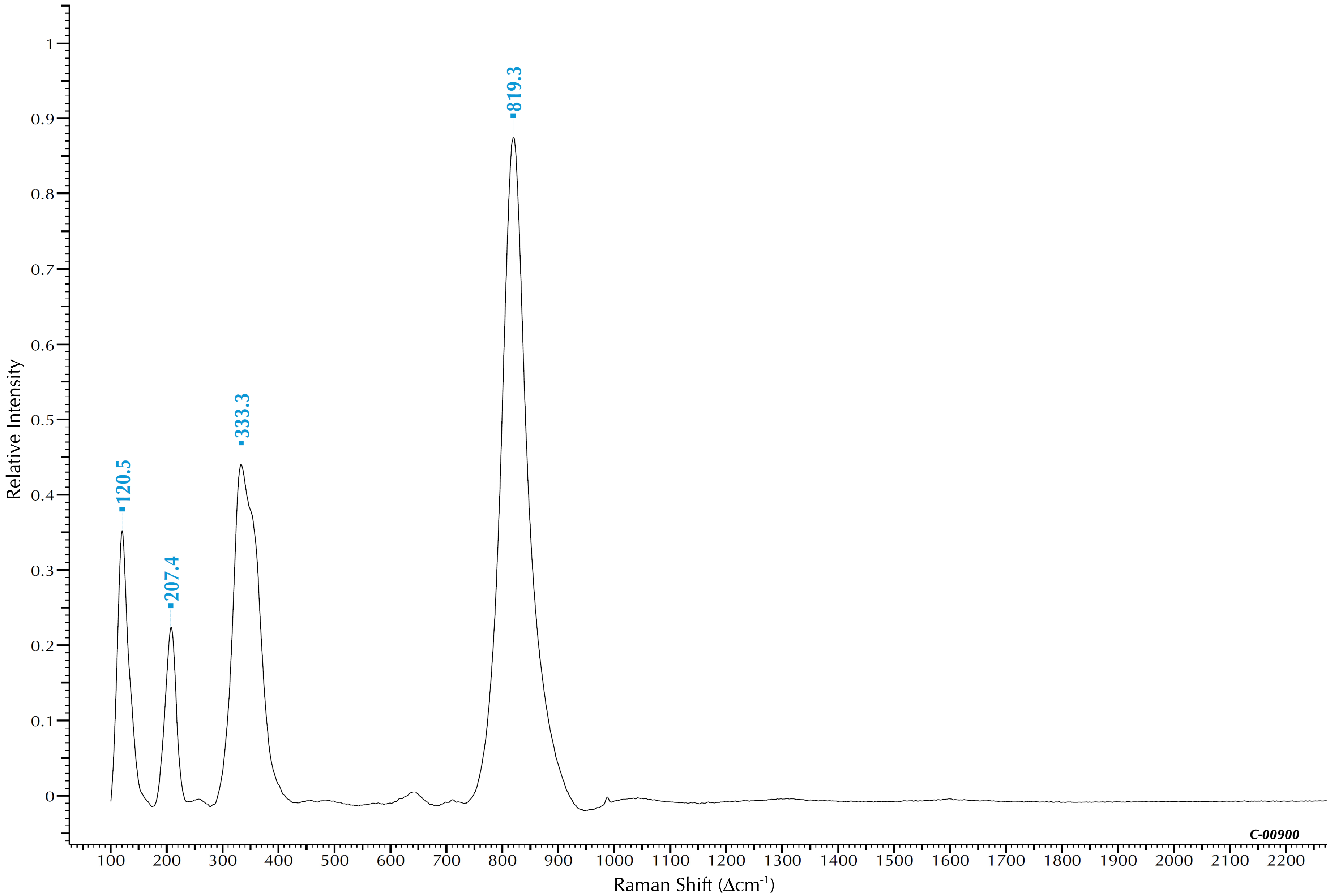
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 18792

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 184



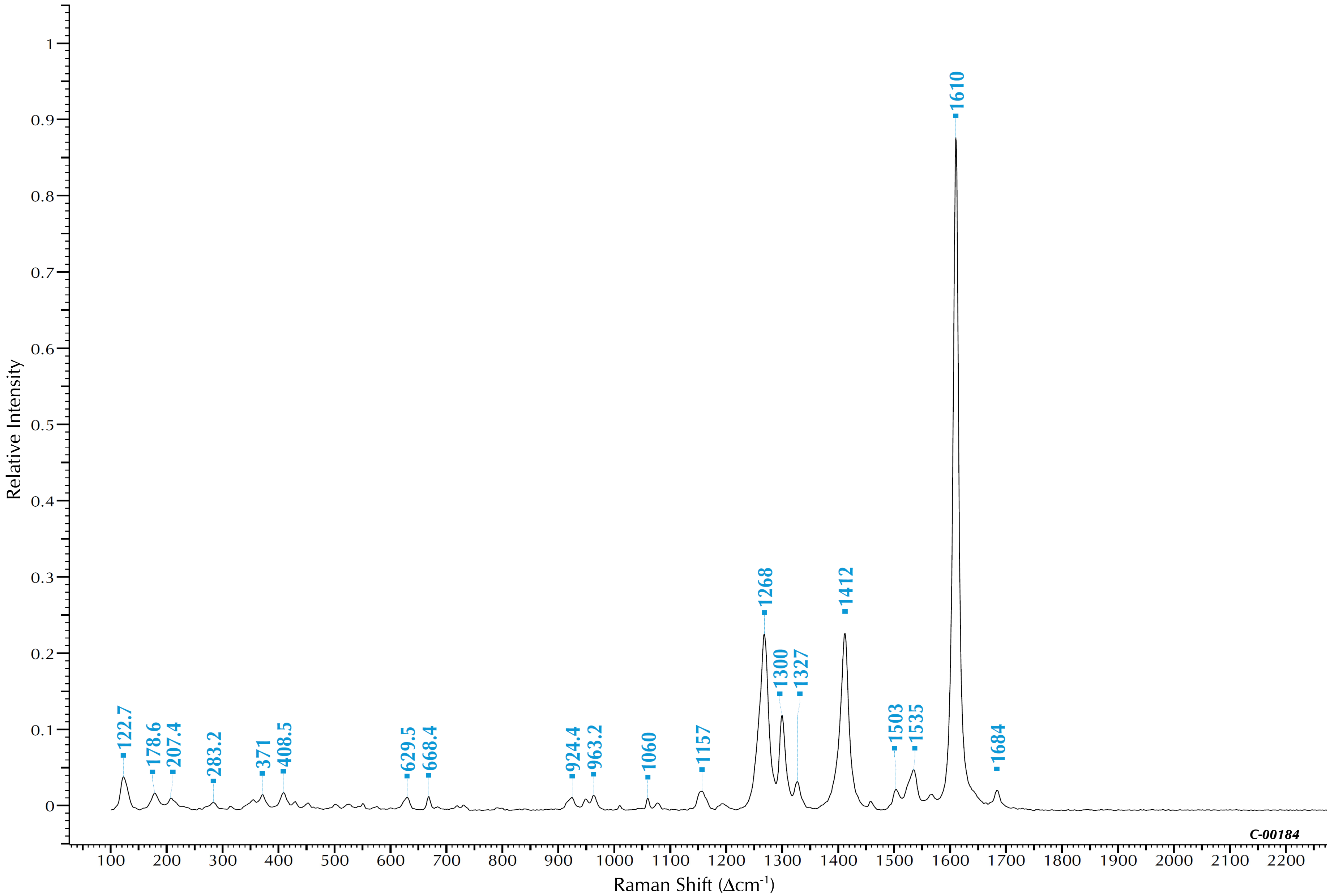
Chemical Category: Inorganic - Vanadate
Constitution Number: 771740

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 5

Microtrace LLC

C.I. Pigment Yellow 188



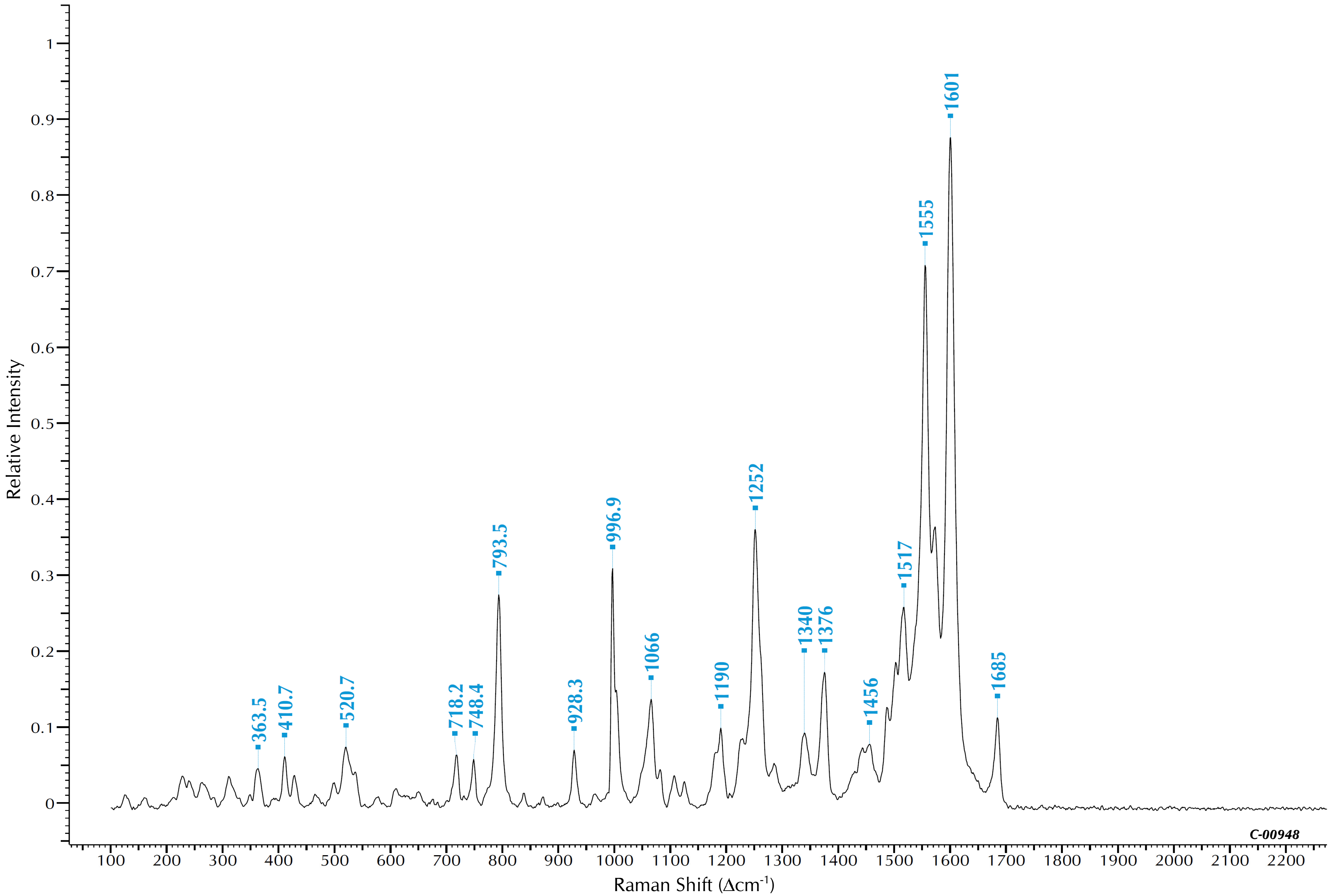
Chemical Category: Organic - Azo - Disazo - Diarylide
Constitution Number: 21094

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 0.83
Quality Index 3

Microtrace LLC

C.I. Pigment Yellow 191



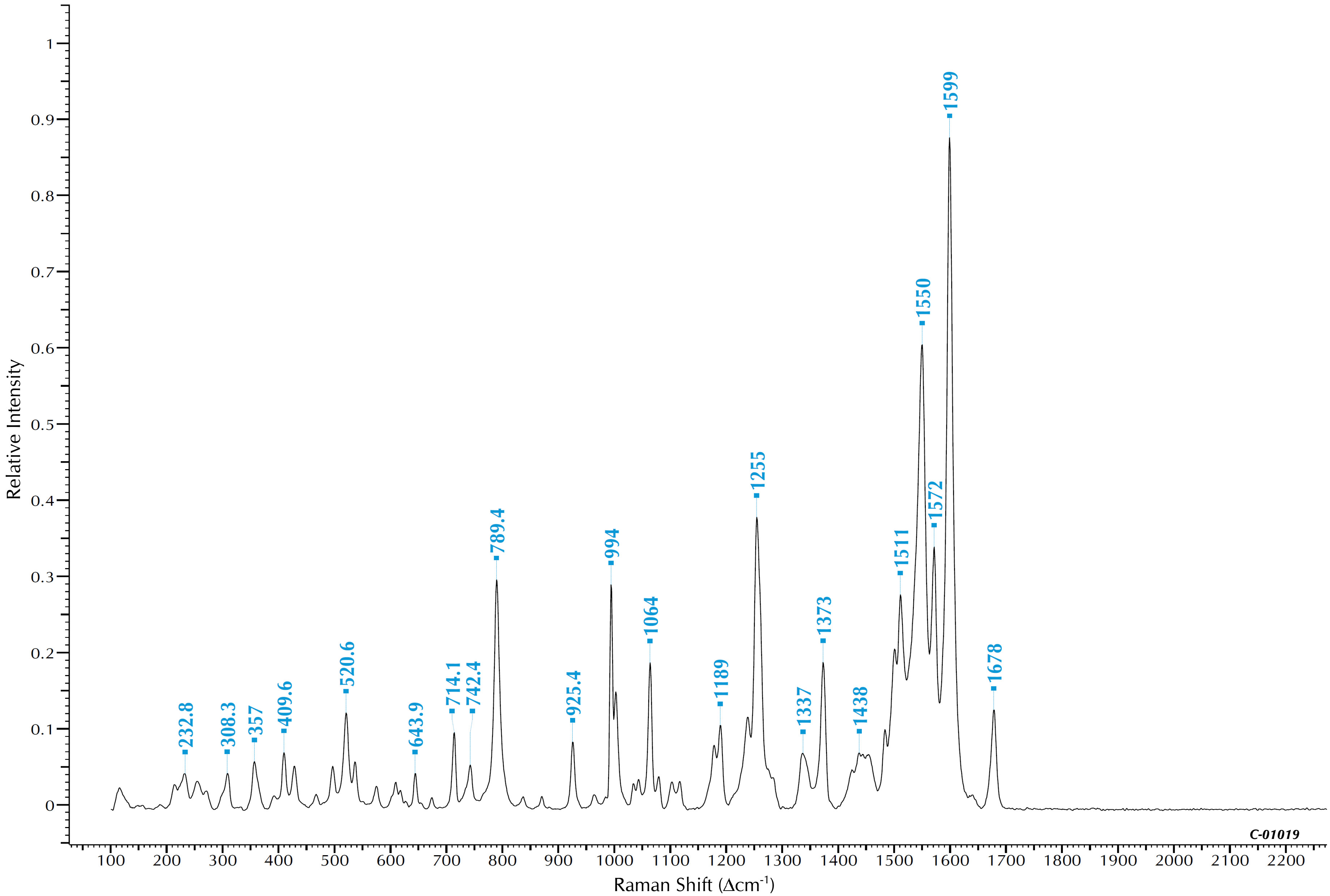
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 18795

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 191:1



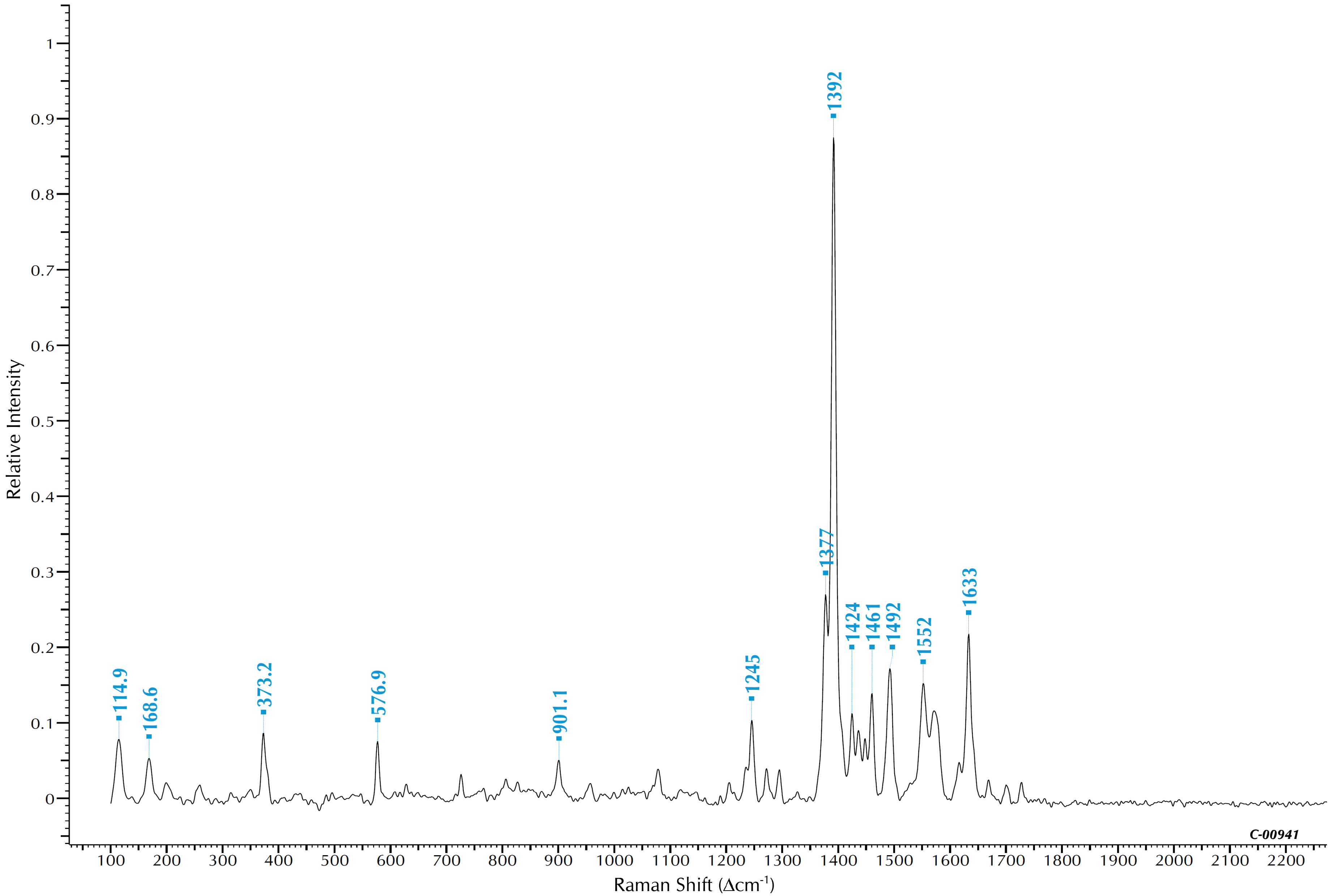
Chemical Category: Organic - Azo - Monoazo - Lakes
Constitution Number: 18795:1

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 213



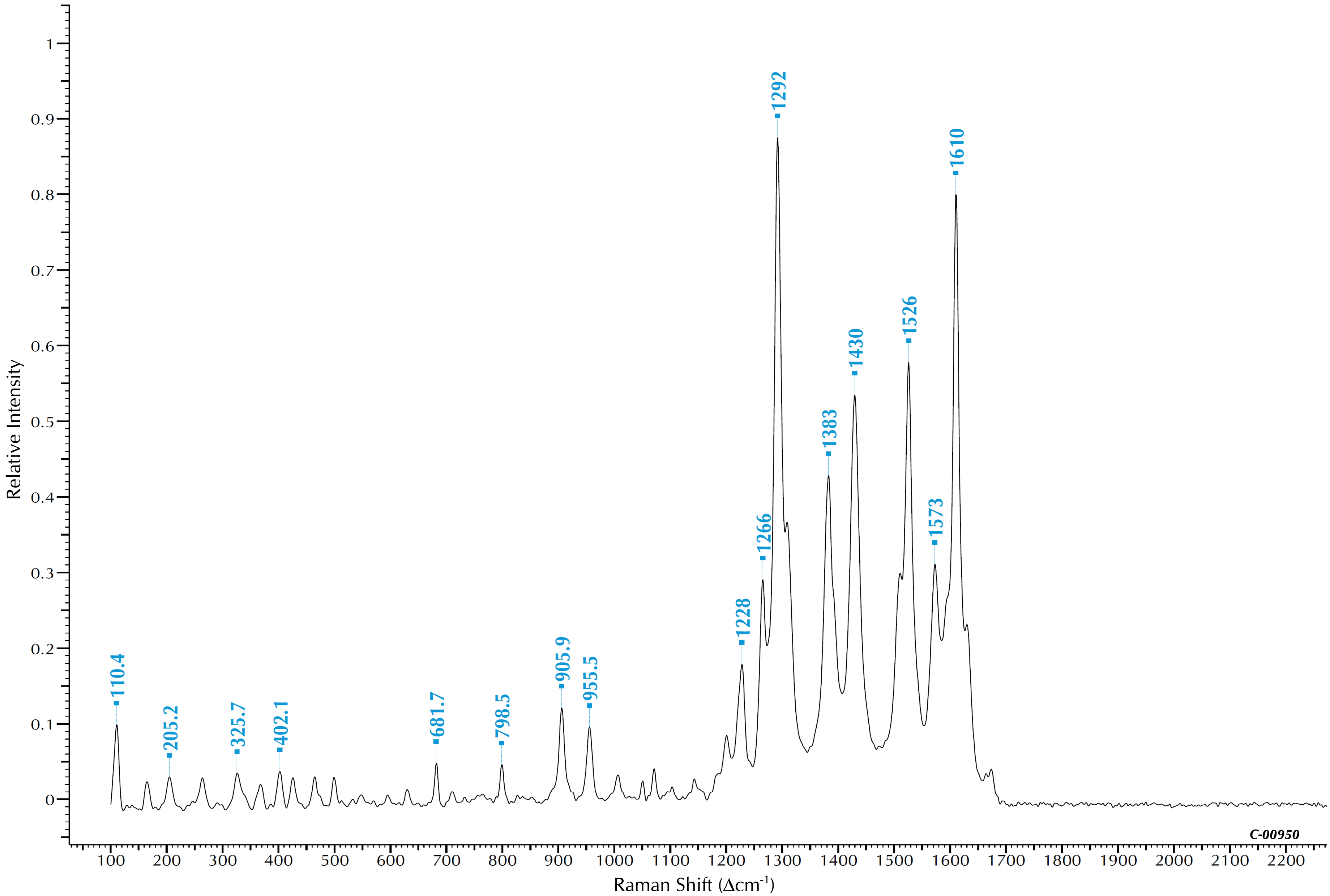
Chemical Category: Organic - Other - Monoazo Chinazolodian
Constitution Number: 117875

Bleaching Time (s): 120
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 214



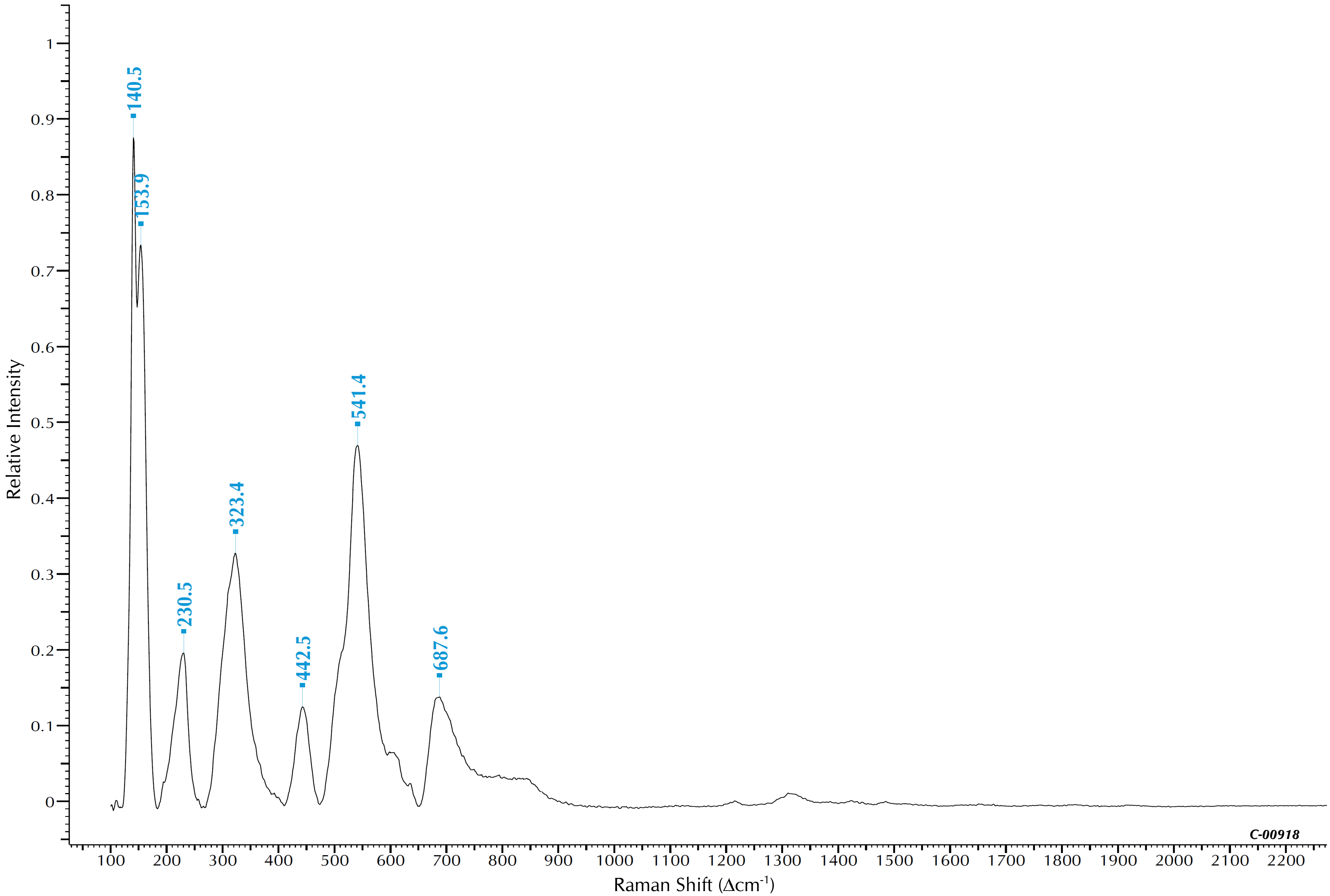
Chemical Category: Organic
Constitution Number: Confidentia

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 2

Laser λ (nm) 785
Power (mW) 2.94
Quality Index 1

Microtrace LLC

C.I. Pigment Yellow 216



Chemical Category: Inorganic - Titanate
Constitution Number: Unknown

Bleaching Time (s): 0
Acquisition Time (s): 10
Accumulations: 1

Laser λ (nm) 785
Power (mW) 6.04
Quality Index 1

Microtrace LLC