An eminent event in the scientific literature, this five-volume compendium covers all significant aspects of infrared, near-infrared, and Raman spectroscopy.

Volume 1: 'Theory and Instrumentation' addresses basic theory, analytical strategies, and instrumental considerations and serves as background material for the ensuing volumes in the series: 'Sampling Techniques' (Volume 2), 'Sample Characterization and Spectral Data Processing' (Volume 3), 'Applications in Industry, Materials and the Physical Sciences' (Volume 4), and 'Applications in Life, Pharmaceutical and Natural Sciences' (Volume 5).

When I receive a book for review, I always avoid glancing at the commercial hype on the back cover. Often the book fails to live up to the endorsements. For the Handbook of Vibrational Spectroscopy, however, no such banter appears. Happier still, few accolades would have been tribute enough to this extraordinary achievement.

This five-volume set compiles the experience of many of the leading talents in the field worldwide. Indeed, the author list reads like a veritable who's who in vibrational spectroscopy. Although no book is perfect, mistakes and typographical errors are rare. Each chapter is essentially a stand-alone treatise and although there is some repetition in this approach, it is a small price to pay for its usability as a whole.

References are generally adequate-to-ample although their timeliness varies depending on the emergence of a particular technique or application historically. In some cases the references are biased toward an author's own body of work but this is largely offset by the fact that the authors are generally among the most prolific in a particular field.

For a multi-author work of this scale (some 350 authors!) the uniformity, balance, and clarity throughout are remarkable. Diagrams, figures and tables are plentiful and although color figures are rare, one might fairly characterize this as 'color with purpose'. A glossary of terms is provided in the final volume and the index, weighing in at 47 pages, is remarkably thorough.
Simply put, this is a monumental work and the authors and editors are to be congratulated on producing what will certainly become the standard in the field. Jerome Workman Jr. (Kimberly-Clark Corporation) was 'dead on' in his assertion that "...[this handbook] is certain to become an instant classic" and despite the rather hefty price it should probably be considered a 'must-have' for serious vibrational spectroscopy laboratories.


Part One ('Introduction to the Theory and Practice of Vibrational Spectroscopy') is anchored by a fascinating chapter on the historical development of vibrational spectroscopy. The next few chapters introduce theories of Raman and infrared absorption touching on aspects of molecular vibration, selection rules, group theory, bandwidth, optical constants, and the Fourier transform (FT). Concise mathematics with the avoidance of heavy theoretical ballast will be embraced by newcomers to the field. With few exceptions, complex mathematical derivations are provided as appendices when necessary. Mid-, near- and far-infrared as well as Raman spectroscopy are introduced considering both the gas-phase and condensed phases.

Part Two ('Instrumentation for Mid- and Far-Infrared Spectroscopy') begins with a discussion on resolution. Continuous scanning, polarization, and Fabry–Perot interferometers are considered in separate chapters. Also included in this section are chapters on sources (*i.e.* diode lasers, incandescent sources, synchrotron, free electron lasers) as well as an extensive chapter delineating the selection and use of detectors for the mid- and far-infrared.

Part Three ('Instrumentation for Near-Infrared Spectroscopy') deals with issues specific to the application of the near-infrared (NIR), an area made vital by recent technological advances. Instrumental advances covered include array, miniature, and filter spectrometers, as well as NIR diode sources and the Hadamard transform (HT).
Part Four ('Instrumentation for Raman Spectroscopy') considers aspects unique to Raman spectroscopy including continuously tunable excitation sources, FT-Raman, resonance Raman, ultraviolet (UV) Raman, coherent anti-Stokes Raman spectroscopy (CARS), inverse Raman, and hyper-Raman.

Part Five ('Time-Resolved Spectroscopy') covers in detail the various methods for acquiring dynamic infrared data from the microsecond to the femtosecond timescales (only a single chapter is devoted to the ultrafast regime, however). Time-resolved Raman, however, is not covered at all.

Part Six ('Dichroism and Optical Activity in Vibrational Spectroscopy') presents the basic principles of linear polarization applied to two (dichroism) or three (trichroism) dimensions. Two important areas of vibrational spectroscopy based on circularly polarized light, namely vibrational circular dichroism (VCD) and Raman optical activity (ROA), are also treated.

Part Seven ('Surface-Enhanced Vibrational Spectroscopy') outlines the theory and application of surfaced-enhanced Raman spectroscopy (SERS) for probing adsorbates on surfaces roughened by noble metals. An excellent chapter on the nature and mechanisms of surface-enhanced infrared absorption (SEIRA), a technique complementary to SERS, also appears.

As a testament to the completeness of this handbook, Part Eight ('Other Instrumental Approaches for Vibrational Spectroscopy') discusses other approaches for measuring vibrational spectra including sum-frequency spectroscopy (SFS), inelastic electron tunneling spectroscopy (IETS), high-resolution electron energy loss spectroscopy (EELS), inelastic neutron scattering (INS), infrared cavity ringdown laser absorption spectroscopy (CRLAS), and doubly vibrationally enhanced (DOVE) four-wave mixing.

In the final section of Volume 1, Part Nine ('Calibration Procedures and Standards for Vibrational Spectroscopy'), wavenumber and photometric scale standards, aspects seldom covered adequately in the open literature, are covered in detail. While perhaps not as sexy as other topics within this volume these are perhaps the most important pages for rigorous quantitative analysis.

Although some aspects of instrumentation (e.g. microspectroscopy and imaging) were noticeably lacking from this volume, many do appear in later volumes, probably due to space constraints.

Volume 2 is a compendium of the suite of techniques available for gaining spectroscopic access to the sample. Part One ('Mid- and Near-infrared Transmission Spectroscopy') starts with a chapter on standard sampling techniques. Included for the newcomer are the interference fringe method, mulling, sealed vs. demountable cells, KBr disks, and reflection approaches (specular, internal, and diffuse).

The next chapter is specific to the near-infrared and its application to solid, liquid, and gas samples. The final chapter offers a very interesting overview of long path length gas cells. Beginning with triple- and quadruple-pass Pfundt and White cells of some 60 years ago, the author introduces present-day variations including two-, four-, and six-row variants, the Wilks-Foxboro cell, and long path cells designed for used with lasers (Herriott's cell).

The bulk of Part Two ('Mid-infrared External Reflection Spectroscopy') deals with infrared external reflection spectroscopy (IR-ERS) or reflection-absorption spectroscopy (RAS) as tools for probing molecular structure and modes of bonding at surfaces. Note, RAS is also referred to as grazing incidence reflection (GIR).

Basic concepts and optical treatments for light reflectance from a boundary with absorption are to be found such as anomalous dispersion, the Fresnel formulae, surface selection rules, molecular orientation and tilt angles, polarization modulation, isotropic vs. uniaxial films, and simulation approaches.

Sampling configurations given specific attention include thin films (multilayered systems, Langmuir–Blodgett films, SAMs [self-assembled monolayers], vacuum-evaporated films) on highly reflecting metallic substrates, thick organic films on metal, thin films on dielectrics, adsorbates on single-crystal surfaces, monolayers at the air–water interface, and gas adsorption at a
metal surface [e.g. CO on Co(0001)]. Two other related surface-sensitive optical techniques are also covered in separate chapters: Fourier-transform surface plasmon resonance (FT-SPR) and IR ellipsometry.

The first two chapters of Part Three ('Mid-infrared Internal Reflection Spectroscopy') introduce the history, principles, theory, and application of mid-infrared internal reflection spectroscopy (IRS). Because the origin of IRS is rooted in the existence of an evanescent field generated from a standing wave established at a totally reflecting interface, the electric field amplitude is logically treated as a function of angle-of-incidence for the semi-infinite bulk case as well as the thin film case.

The authors provide a nice overview of internal reflection element (IRE) material specifications (from α-alumina to zirconium) as well as common IRE geometries. Although the references are a bit dated, the discussion is still highly relevant to modern IRS analysis. The third and final chapter of this subject area provides a basis for understanding multiple internal transmission spectroscopy and its utility in monitoring silicon wafer bonding and hydrogen-induced exfoliation.

Part Four ('Diffuse Reflection Spectroscopy') contains five tightly written chapters on all aspects of diffuse reflection (DR) spectrometry. The first chapter surveys the theoretical underpinnings of continuum theories of DR with emphasis on Kubelka–Munk theory, a theory which, despite decades of debate, confusion, and theory failure under certain conditions, remains the most popular theory of DR. The next chapter provides an alternative approach and examines aspects of discontinuum theories of DR including the mathematics of plane parallel layers, assignment of the absorption and scattering properties to an individual particle, and the set of assumptions needed to 'assemble' particles into layers.

The remainder of Part Four emphasizes instrumental aspects of DR including, but not limited to, sample preparation and sampling strategies, spectrometer design considerations, reference measurements, NIR radiant collection schemes, and commercial DR accessories. The final chapter is devoted entirely to integrating spheres and design-associated error sources.

Part Five ('Other IR Sampling Techniques') deals with miscellaneous and less routine IR sampling techniques not discussed specifically elsewhere in the five-volume set. The first chapter introduces
infrared emission spectroscopy (IRES), a technique concerned largely with thermal emission of molecular systems. After laying down some laws of blackbody and non-blackbody thermal emission, the author turns his attention to instrumental distortions, the influence of sample thickness, temperature and physical state, and finally closes with a very thorough discussion of instrumentation requirements, spectral interpretation, and specific applications.

The following chapter provides details on the theory and application of transient infrared spectroscopy (TIRS), a process stream variant of IRES. The same authors are also responsible for the subsequent chapter on photoacoustic spectroscopy. The first half of this chapter offers a lucid discussion of photoacoustic signal generation and interpretation while the remainder discusses instrumentation and sample types including layered and gradient materials. A chapter on one of the more exotic techniques in the Handbook, photothermal deflection spectroscopy (PDS) is testament to the completeness of the volume.

Part Six (‘Raman Spectroscopy’) consists of four chapters covering disparate aspects of Raman sampling. The first deals predominantly with the logistics of measuring the relatively weak Raman features in the presence of high fluxes of adventitious light. There is also slight coverage of aspects of sample environment control (e.g. temperature, pressure, humidity, as well as a perfunctory nod in recognition of laser safety).

Chapter 2 provides a beautifully illustrated overview of Fourier-transform Raman spectroscopy. The third chapter complements the surface-enhanced Raman scattering (SERS) chapter in Volume 1. Here, however, the emphasis is on SERS-based Raman probes such as metal electrodes, colloids, nanostructures, and coatings. The final chapter discusses morphology-dependent Raman measurements made using optical and electromagnetic fields for trapping. A chapter devoted to various sampling formats for resonance Raman is conspicuously absent although instrumental aspects were covered in sufficient detail in Volume 1.

Part Seven (‘Low Temperature and High Pressure Sampling Techniques’) begins with a survey of cryogenically liquefied gases as solvents for vibrational spectroscopy with inclusion of substantial detail on the associated cell design. This chapter is logically followed with a chapter on the more elegant low-temperature method of matrix isolation which is well-suited to studying short-lived and insoluble species such as free radicals and refractory materials.
Chapters 3 and 4 focus on the development and design of the diamond anvil cell (DAC) to generate kbar pressures. Applications to the vibrational studies of coordination complexes as well as use of the DAC in forensics are discussed. The development here, although brief, is lucid and to the point.

Part Eight ('Microscopy'), organized into seven full chapters (123 pages), treats the development of vibrational imaging in an orderly fashion. Chapter 1 begins with some very basic concepts like the confocal effect and resolution criteria and proceeds to sampling modes of transmission and reflection IR microspectroscopy. Chapter 2 treats FT-IR imaging made possible with the development of multichannel array detectors. Nearly half of the chapter is devoted to applications of FT-IR imaging in the polymer, agricultural, and biomedical fields.

The 'sleeping dwarf' NIR microspectroscopy is the subject of the next chapter. The unique potential of NIR microspectroscopy in pharmaceutical formulation is evident from the well chosen examples. A detailed overview of Raman imaging is provided in the next two chapters. Topics covered range from mapping configurations (point-by-point, line, and widefield imaging) to analysis types (multivariate, correlation, factor, and cluster) to target applications (semiconductors, fuel cells, meteorites, minerals, pharmaceuticals, and biomaterials). Chapter 6 shows how the coupling of near-field optics to vibrational spectroscopy opens the door to nanospectroscopy. The final chapter further develops this theme with state-of-the-art technologies like IR or Raman near-field scanning optical microscopy (NSOM) and localized microthermal analysis.

The variety of methods used to probe the specific chemical composition and structure deep (in a molecular sense) into a sample (i.e. depth profiling) are explored in Part Nine ('Depth Profiling by Vibrational Spectroscopy'). Nondestructive alternatives to microtome slicing including attenuated total reflection (ATR) FT-IR, confocal Raman, and photoacoustic spectroscopy are covered. The refined algorithms making such possible are accentuated throughout.

Part Ten ('Optical Conduits for Vibrational Spectroscopy') deals with fiber optics and fiber-optic probes. The initial chapter gives the reader some basic terminology and introduces the principles of light propagation in optical fibers of various types (single- or multimode, step-index, graded-index, polarization-preserving). The next several chapters focus on aspects of mid-infrared (4000–400 cm⁻¹) optical
fibers and fiber-optic probes. Core materials, probe head design, and numerous specific application examples are briefly discussed. There is some repetition here but this serves the interested reader well. The next two chapters cover the specifics of near-infrared and Raman fiber-optic probes. A chapter on the transmission characteristics of metallized light pipes for vibrational spectroscopy concludes the section.

Nine chapters on multidimensional or hyphenated vibrational techniques make up Part Eleven ('Hyphenated Techniques'). This section serves as an excellent entry point into the voluminous literature. It begins with the elder analytical technique gas chromatography/Fourier-transform infrared spectroscopy (GC/FT-IR).

Other techniques include FT-IR coupled with mass spectrometry (MS), supercritical fluid chromatography (SFC), high-performance liquid chromatography (HPLC), and flow injection analysis (FIA). Raman-detected capillary electrophoresis and the coupling of thin layer chromatography (TLC), thermal methods like thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) with FT-IR and Raman round out the section.

The final chapters of Volume 2 deal with real-time and near real-time atmospheric monitoring using vibrational approaches ('Atmospheric'). Contributions on extractive and open-cell FT-IR as well as light detection and ranging (LIDAR) appear. These chapters may well have wandered from the Volume 4 grouping of chapters 'Atmospheric and Astronomical Vibrational Spectroscopy', but they were fairly included here to emphasize the unique sampling (large gas flow cells, telescopes, retroreflectors) needed to implement them.


Volume 3 covers spectral analysis for sample identification and structure determination using the same quality approach established in the two earlier volumes. Many of the advances made
in modern spectral data processing owe a debt to Moore's law and are described in detail in this volume. A chapter on Fourier-transform methods is mindfully absent given the existence of many superbly detailed handbooks and texts in that area.

Section One ('Spectra–Structure Correlations') is a massive 199 pages, a third of the entire volume. The first three chapters review classical spectra–structure correlations and factors affecting group frequency assignments for the mid-, near-, and far-infrared as well as for Raman. Difficulty in structural assignment due to the presence of overtones and Fermi resonances are presented.

The next two chapters follow this same approach but for inorganic and coordination compounds and for organic polymers. There are also extensive tabular data in these sections, however, inorganic coordination compounds are lightly covered and spectra of organometallic compounds are merely referenced. Although there is no mention of biopolymers, these are covered in Volume 5.

The next chapter deals exclusively with theoretical and experimental perspectives on the centrally unique hydrogen bond. Presented in the seventh chapter are methods to pinpoint the effect of a particular atom on the normal modes of the vibrations using selective isotopic substitution. Use of automated spectral searching algorithms for mid-, and near-IR as well as Raman spectra are presented next as well as some of the preprocessing applied in building spectral libraries.

The final chapter gives attention to the ways in which expert systems can aid the spectroscopist in data reduction and organization. These artificially intelligent (AI) algorithms require 'training' using approaches like fuzzy logic, pattern recognition, and neural nets.

Section Two ('Group Theoretical and Numerical Approaches to the Calculation of Vibrational Spectra') covers computational methods used to derive the spectra of underlying chemical structures from first principles. These various approaches are embodied in several mathematical methods including those of group theory, normal coordinate analysis, Hartree–Fock-based theory, density functional theory (DFT), and molecular mechanics (MM). The final article in this section covers the prediction of vibrational intensities from molecular orbital (MO) calculations and parametrization according to suitable models.
The third section ('Discriminant Analysis') is headed by a general discussion of the multivariate branch of analysis known as chemometrics. The second article deals with several parametric statistical approaches to computer-driven spectral identification including linear discriminant analysis (LDA), application of Mahalanobis distances, principle component analysis (PCA), partial least squares (PLS) modeling, and the lesser known logistic regression.

The following article describes the use of artificial neural networks (ANNs) to achieve these same ends using a multitude of ANN architectures including multilayer feed-forward, Kohonen self-organizing feature maps, and Hopfield, bidirectional associative memory, radial basis function, counterpropagation, Hamming, or holographic networks.

The final contribution in this section deals with non-ANN methods to perform this identification with focus on nonparametric methods such as cluster analysis (hierarchical versus nonhierarchical), discriminant analysis (linear and quadratic, and K nearest neighbor), and soft independent modeling of class analogies (SIMCA).

A description of the general theory for perturbation-based 2-D correlation analysis can be found in the first article of section Four ('Two-Dimensional (2-D) Analysis'). The second article is heavily application oriented with specific examples of 2-D MIR, NIR, and Raman spectroscopy correlation studies given for polymers, liquid crystals, chemical reactions, and proteins. By spreading peaks along a second dimension, it is clear that 2-D analysis has the ability to greatly simplify complex spectra consisting of multiple overlapping peaks, enhance spectral resolution, and unambiguously assign the coupling of bands resulting from external perturbation.

The section 'Spectral Enhancement and Band Resolution Techniques' presents the varied computational methods to determine the underlying band structure of noisy or convoluted spectra. The first chapter clearly speaks to the more commonly used ways to achieve spectral smoothing such as boxcar, Savitzky–Golay, maximum likelihood, maximum entropy, and Fourier and wavelet smoothing. Methods for computing derivatives are also presented (e.g. gap, Savitzky–Golay, and Bayesian derivatives).

The next article deals predominantly with complex Fourier methods to perform these tasks. The final article 'Curve-fitting: Modeling Spectra' describes nonlinear methods to achieve spectral
deconvolution. The author pays a good deal of attention to algorithm choice and points out the fact that the only such algorithm now in widespread use (i.e. the Levenberg–Marquardt algorithm) is some 40 years old!

The first two articles of Section Six ('Quantitative Analysis') deal with classical quantitative analysis issues like the Beer–Lambert–Bouguer law, excursions from Beer's law, and common sources of error. The following article provides an overview of calibration/validation procedures and classical and modern chemometric algorithms to achieve this for individual-wavelength and full-spectrum methods.

The ensuing chapters consider in greater detail inverse least squares and classical least squares, principle component regression and partial least squares regression (currently, the two most popular algorithms in modern quantitative spectral analysis), and genetic algorithms. The final chapter deals briefly with oft-overlooked issues of data transfer, formatting, storage, and archival in light of regulatory and third-party software issues.

The final section 'Anomalies, Artifacts and Common Errors in Using Vibrational Spectroscopy Techniques' discusses common sources of artifact and spectral distortion arising from sample preparation, instrument characteristics, and data processing sources for mid-infrared, near-infrared, and Raman spectroscopy. These pages are invaluable for the bench experimentalist. A glossary of abbreviations and terms used in chemometrics completes the volume.


As suggested by an Associate Editor of the *Handbook of Vibrational Spectroscopy*, the widespread lack of appreciation for the practical capabilities of vibrational spectroscopy may stem in part by the fact
that in the past [and even now] vibrational spectroscopy was/is often marginalized at an early stage in a scientist's career. Given the dozens of specific applications for vibrational spectroscopy detailed in Volumes 4 and 5, however, there is no reason that this should be the case. Volume 4 is intended to illustrate the utility of vibrational techniques in the physical and material sciences while the final volume (Volume 5) does so for the biosciences.

The first section 'Analysis and Characterization of Polymers and Rubbers' consists of 10 articles (169 pages), a testament to the extensive use of vibrational spectroscopy in this area. The first article, serving as a prelude to more specific articles in the section, discusses sampling modes and basic concepts in polymer analysis (e.g. molecular orientation, end group branching, blend miscibility, hydrogen bonding, curing, degradation, oxidation, delamination).

The following article further discusses infrared and Raman spectroscopy as tools to probe the molecular microstructure and morphology of polymers and rubbers. Stereoregularity, chain conformation and defects in conformation, isomerism in rubber compounds, and hydrogen bonding are discussed. The third article summarizes infrared and Raman studies of physical phenomena such as chain packing and orientation, accordion motion, and phase transitions (thermal-, crystallization-, or strain-induced) within polymers and rubbers. Because of their industrial importance, polymer composites such as reinforcement treatments and interphases, thermoplastics, and thermosets are exclusively dealt with in the next article. Similarly, structural studies of doped as well as pristine conducting polymers occupy the following article.

Article six focuses on state-of-the-art applications of linear dichroism in infrared spectroscopy toward molecular orientation studies in elastomeric networks and bimodal polymer melts. The following article describes the identification of weathering and chemical and photooxidation products in aged polymer materials using infrared spectroscopy. The remaining articles review determination of various optical, dielectric, thermal, and solar properties of polymers by vibrational spectroscopy.

The first article in the next section ('Rheo-optical Measurements of Polymers and Rubbers') demonstrates the versatility of rheo-optical FT-IR and FT-NIR spectroscopy for characterizing transient microstructural changes occurring during polymer deformation and stress relaxation in polymers. The other article under this subject heading emphasizes the theory and practice of dynamic infrared linear dichroism (DIRLD) to do the same.
The section 'Materials Science' covers specific material systems whose study has benefited greatly from the use of vibrational spectroscopy. The first article summarizes vibrational spectroscopy of graphite, diamond, silicon single crystals and silicon dioxide films. The next article offers additional detail into infrared studies of device-quality silicon like epitaxial silicon. The recent and potential applications of Raman scattering to the study of semiconductors and high-Tc superconductors are surveyed in the following two articles.

The next article emphasizes the analytical strengths of infrared absorption and Raman scattering in the study of thin organic films including self-assembled monolayers (SAMs) and Langmuir–Blodgett (LB) films. The final article speaks to the structural elucidation of glassy and amorphous materials (GAMs) such as fluorinated silicates, phosphosilicates, silicon carbide, and organosilicates. Some key topics such as Raman studies of carbon nanomaterials (carbon fibers, nanotubes, and fullerenes) somehow missed the opportunity to appear here.

The unique potential afforded by coupling/hyphenating vibrational spectroscopy with electrochemical systems is dealt with in the next section ('Spectroelectrochemistry'). Two articles focus on infrared and Raman spectroelectrochemistry, respectively, and review important aspects of experimentation while highlighting areas of past and current progress.

The next section 'Process Vibrational Spectroscopy' also consists of two articles. The first discusses process monitoring by mid- and near-infrared Fourier-transform spectroscopy and the latter by Raman scattering. These articles are among the lengthiest in the Handbook (33 and 32 pages, respectively) and are essential reading for those needing to acquire a ready familiarity with the material without being out of their depth.

The next section 'Atmospheric and Astronomical Vibrational Spectroscopy' will remind readers of the 'Atmospheric' section of Volume 2, however, the focus here is more on target applications and less on the unique sampling requirements associated with them. The first article presents some easy-to-digest introduction to astronomical vibrational spectroscopy; both astronomical objects and associated interstellar molecules are described.

FT-IR spectrometry as a technique for measuring global atmospheric composition and trace gas fluxes in 'clean' air is the focus of the next article. Passive open-path FT-IR remote sensing and remote Raman spectroscopy are discussed in separate
chapters. The final article describes the contributions of infrared spectroscopy to fire science and combustion chemistry.

'Industrial Applications of Vibrational Spectroscopy' begins with a contribution from the automotive industry. Specific examples discussed are quite varied ranging from vehicle emission monitoring to studies of catalytic converters to probing of interfacial friction and wear. The many interesting problems addressed by the color chemist using vibrational spectroscopies are explored in the next article. These applications include simple chemical group identification, and studies of tautomerism, hydration and polymorphism. These discussions continue in the following article which discusses the use of vibrational analysis as it relates to the paint industry. A history of infrared and Raman sampling and limitations in the pulp and paper industry concludes the section. Applications discussed include lignocellulosic determination, extractive and contaminant analysis, as well as studies of Kraft pulping, and photo-yellowing.

The section 'Forensic Applications of Vibrational Spectroscopy' offers an interesting excursion. For the reader familiar with vibrational spectroscopy, this is fascinating bedtime reading. The first article begins with a survey of the more common inorganic and organic pigments used through the ages to illuminate artifacts and proceeds to applications of Raman spectroscopy in the conservation, dating, and authentication of art objects such as paintings, ceramics, papyri, icons, polychromes, and bronzes. The other article discusses the use of vibrational spectroscopy in forensic laboratories. Potential applications include linking a particular material (e.g. a textile fiber, automotive paint, tape adhesive) to a crime scene, proving the origin of a fraudulent letter, or identifying illicit drugs or explosive residues.

The section 'Catalysis' examines the role of vibrational spectroscopy in providing information on the nature and properties of solid catalytic surfaces. The topic of the first article is sulfide and nonzeolitic oxide catalysts. The following article fills the obvious gap and covers the vibrational spectroscopy of zeolites and zeotypes. The other two articles discuss supported metal catalysts and adsorbed species on finely divided metal catalysts.

The next section ('Other Applications of Vibrational Spectroscopy') offers a miscellany of highly specialized vibrational spectroscopic applications. The first two articles discuss vibrational studies of liquid crystals and supercritical fluids. The next article reviews the photochemistry of inorganic and organometallic compounds in
hydrocarbon matrices. Next, a timely article which serves as an excellent reference tool for those interested in the use of vibrational spectroscopy to study explosives.

A fascinating article illustrating vibrational spectroscopy as a geological tool in the identification of mineral groups and for probing their behavior under pressure and/or temperature extremes appears next. Finally, recent extension of IR and Raman methods into soil and environmental sciences is introduced. A few of these articles might have found an appropriate home elsewhere in the Handbook but this is a small matter.

Whereas undergraduate exposure to IR generally consists of the interpretation of the gas-phase spectra of HCl and DCl and possibly simple product structural characterization in the organic lab, hands-on experience is virtually nonexistent for Raman scattering. In response to this marginalization of vibrational techniques and limited early exposure, the section 'Vibrational Spectroscopy in Education' is an excellent selection with which to end the volume. The two articles in this section address infrared and Raman spectroscopy and are excellent teaching resources for instructors designing undergraduate curricula.

**Volume 5: 'Applications in Life, Pharmaceutical and Natural Sciences'** contains 28 chapters divided into five subject areas: 'Biomedical Applications', 'Biochemical Applications', 'Pharmaceutical Applications', 'Food Science', and 'Agricultural Applications'. This, the final volume, provides the reader with a wonderful snapshot of contemporary research at the busying intersection of vibrational spectroscopy and life sciences.

As for the preceding four volumes in the series, the contributions are from pioneers, imaginative frontrunners and aficionados in their respective fields. As with the previous volume, even the most cursory trawl through its pages and the accompanying illustrations and figures cannot fail to generate numerous research ideas.

The volume begins with a ten-article section encompassing many of the various 'Biomedical Applications' of vibrational spectroscopy which have emerged in recent years. The first article artfully introduces aspects of pathology which are accessible to vibrational interrogation. No longer the Rodney Dangerfield of vibrational spectroscopy, NIR spectroscopy for noninvasive medical diagnosis has "gotten some respect" being dealt with here in back-to-back articles as well as a later article.
The stability of today's spectrometers combined with improved quantitative algorithms and advanced computing power has resulted in the clinical adaptation of many vibrational techniques. General clinical analyses of biofluids like blood, plasma, urine and amniotic fluid are introduced in a single article while another article exclusively treats strategies for noninvasive and ex-vivo glucose monitoring.

The next article delivers an authoritative and comprehensive review not only of the major principles, but also of many fine details of using vibrational spectroscopic methods to study microorganisms at the whole cell level. The exciting, if not daunting, task of screening for cancers, and hopefully assisting in prognosis and treatment, is the subject of the next article. The final two articles in this section treat biomedical imaging modes, ex-vivo and functional vibrational imaging.

'Biochemical Applications' is the theme of the second cluster of chapters. Excellent tutorials on infrared and Raman spectroscopy of proteins are provided in the first two articles. Individual chapters on the vibrational spectroscopy of lipids, nucleic acids, carbohydrates or glycoconjugates, and membranes also appear. Raman and UV-resonance Raman (UVRR) studies of viral assemblies are addressed in clear fashion here as well. Finally, the versatility of time-resolved FT-IR difference spectroscopy as a tool for probing nanosecond and slower molecular reaction mechanisms of proteins is explored in some detail.

Although the contributions in this section were of paramount quality, I was surprised to find no chapter devoted to isotope-edited biomolecular spectroscopy. Also 'missing' are other important recent developments of notable significance such as fast laser T-jump methods.

Although without exception the major pharmacopoeia focus on gross identity, sample form is intimately related to pharmacological activity. The use of vibrational spectroscopy in the identification and characterization of discrete and formulated pharmaceutical products is the topic of the third section in this volume, 'Pharmaceutical Applications'.

The text of the first article provides a tutorial of several pharmaceutical forms (polymorphs, solvates, hydrates) while the following article expounds on the formulation analysis of solid dosage forms using various vibrational means. The third article deals exclusively with quality control/validation issues relating to
the widespread use of NIR in the pharmaceutical industry. Lastly, the foundation for vibrational analysis of resin-bound combinatorial libraries, an increasingly popular modality in the pharmaceutical industry for the discovery of pharmacologically active substances, is provided.

The last two sections 'Food Science' and 'Agricultural Applications' are closely related and will be considered together. Indeed, these applications have a heavy reliance on NIR, a fact which bears great economic importance. For example, perhaps not common knowledge, a farmer is paid for a crop or agroproduct according to the NIR-determined protein or oil content in material.

In the first section, authors do a nice job explaining the application of NIR spectroscopy (or MIR or Raman) in the analysis of the brewing process as well as dairy products and wine. The theme continues in the second section which covers vibrational spectroscopic analyses of forages, grains and cereals, and other agricultural products.

The Handbook closes with a useful compilation of bio-specific terms, and an abbreviation and acronym list as well as a glossary of general terms used in vibrational spectroscopy, the latter being some 50 pages. A fairly exhaustive index caps this monumental effort.

Simultaneously a voluminous reference and a wonderful springboard for newcomers, the pentaology will have lasting value for both the beginner and veteran researcher in this dynamically developing field. Overall, the Handbook is a marvel of thoroughness and attention to detail and is sure to become the gold standard in the field. All involved are to be thoroughly congratulated!

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