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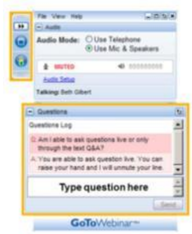

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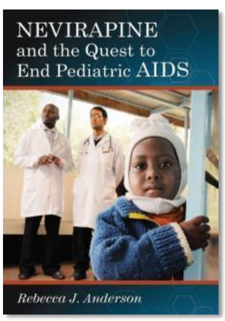

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Cannabis Chemistry 201

ACS Webinar
November 6, 2014

Christopher J. Hudalla, Ph. D.

Cannabis Chemistry 101: Review

- **History of Cannabis**
  - Legal status in the US
- **Endocannabinoid System**
  - Therapeutic benefits
- **Chemical Complexity**
  - Phytochemical constituents
  - Potential contaminants
  - Matrix complexity
- **Biosynthetic Pathways**
  - Formation of cannabinoids
- **Cannabinoid Reactions**
  - Degradation/Decarboxylation
- **Opportunities for Analytical Chemistry**
  - Application of modern technologies
  - Ensure consumer safety
  - Research opportunities

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Role of Analytical Chemistry

- **Ensuring Consumer Safety**
  - Confirm products are free from contamination
  - Assist in determining proper dosage
- **Optimization of Cultivation Practices**
  - Monitoring nutrient uptake
  - Early identification of phenotypes
- **Design and Development of Marijuana Infused Products (MIPs)**
  - Optimization of extractions and processes
  - Quantitation required for product labeling

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Audience Poll

What is typically the most abundant cannabinoid found in cannabis?

- ☐ **THC (Tetrahydrocannabinol)**
- ☐ **CBD (Cannabidiol)**
- ☐ **THCA (Tetrahydrocannabinolic Acid)**
- ☐ **CBDA (Cannabidiolic Acid)**

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Analytes and Analytical Techniques

	Analyte	Analytical Technique
Phytochemicals	Cannabinoids	TLC, GC, HPLC, UPLC, **CC (SFC)**
	Terpenes	**GC**
	Water (Residual Moisture)	Gravimetric, Water Activity
Contaminants	Heavy Metals	AA, ICP, ICP-MS, **TXRF**
	Volatile Organic Compounds (VOCs)	**Headspace GC**, GC/MS
	Mycotoxins	**ImmunoAffinity (IA) Assays**
	Microbiological Contaminants	Cultures, qPCR
	Pesticides/Plant Growth Regulators	LC/MS, GC/MS

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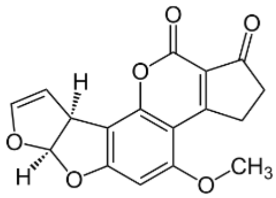
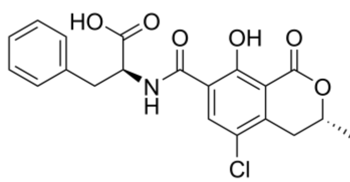
Mycotoxins

- **Four Key Aflatoxins: B_1, B_2, G_1, G_2**
  - Produced by some Aspergillus molds
  - Results in liver damage



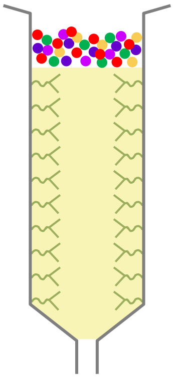
- **Ochratoxin A**
  - Produced by some Aspergillus and Penicillium molds
  - Results in kidney damage and immune suppression



- **Found in many commodities**

ImmunoAffinity (IA) Assays

- **Monoclonal Antibody Based Affinity Chromatography**
  - Extracted sample is loaded on to the column
  - Sample is flushed through the column
  - Mycotoxins are selectively bound to the antibodies
  - Additional constituents are passed through to waste
  - Mycotoxins are collected selectively for analysis



Mycotoxin Testing

Mycotoxin concentrations can be measured with a digital fluorometer. Provides total aflatoxin and total ochratoxin concentrations.

Analysis with LC or LC/MS/MS delivers additional sensitivity and specificity, providing separation and quantitation of the individual mycotoxins.

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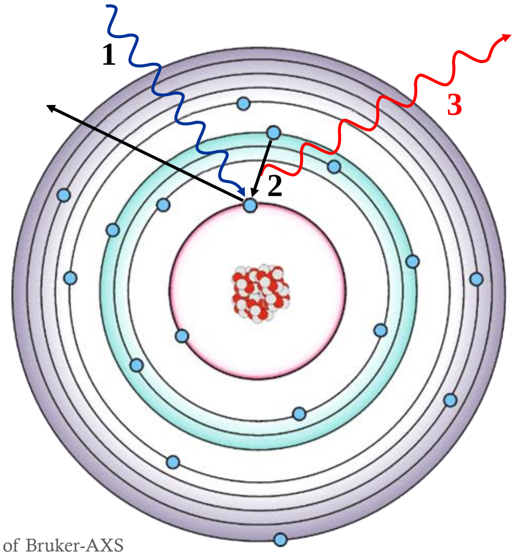
X-ray Fluorescence (XRF) Spectroscopy

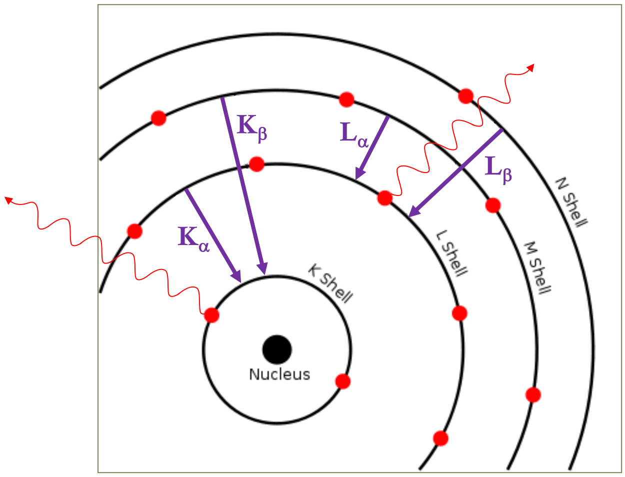


Courtesy of Bruker-AXS

- An X-ray quantum hits an inner shell electron in a (sample) atom. The electron is removed leaving the atom in an excited state (1)
- A electron from a higher orbital will drop down to fill the space. (2)
- The energy difference between the inner and outer shell is balanced by the emission of a photon quantum (fluorescence radiation, 3)
- These transitions are instantaneous. Fluorescence emissions are specific to individual elements, with intensities proportional the concentration of those elements.

X-ray Fluorescence (XRF) Spectroscopy

- **Each element shows a specific line pattern in a spectrum depending on the orbitals involved**
  - L→K transition = Kα line
  - M→K transition = Kβ line
  - M→L transition = Lα line
  - N→L transition = Lβ line
  - *The higher the atomic number, the more "shells" (generally speaking)*



Each element has it's own set of "fingerprints"

Courtesy of Bruker-AXS

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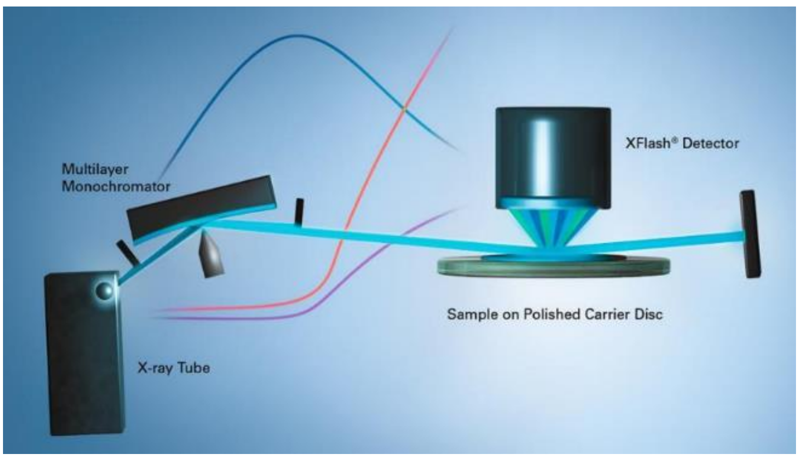
Quantitative Elemental Analysis

TXRF - Total reflection X-ray Fluorescence Spectroscopy



- Provides quantitative multi-element microanalysis
- Lower limits of detection in ppb range
- Meets USP requirements established for pharmaceutical products (USP 232/233)

Courtesy of Bruker-AXS

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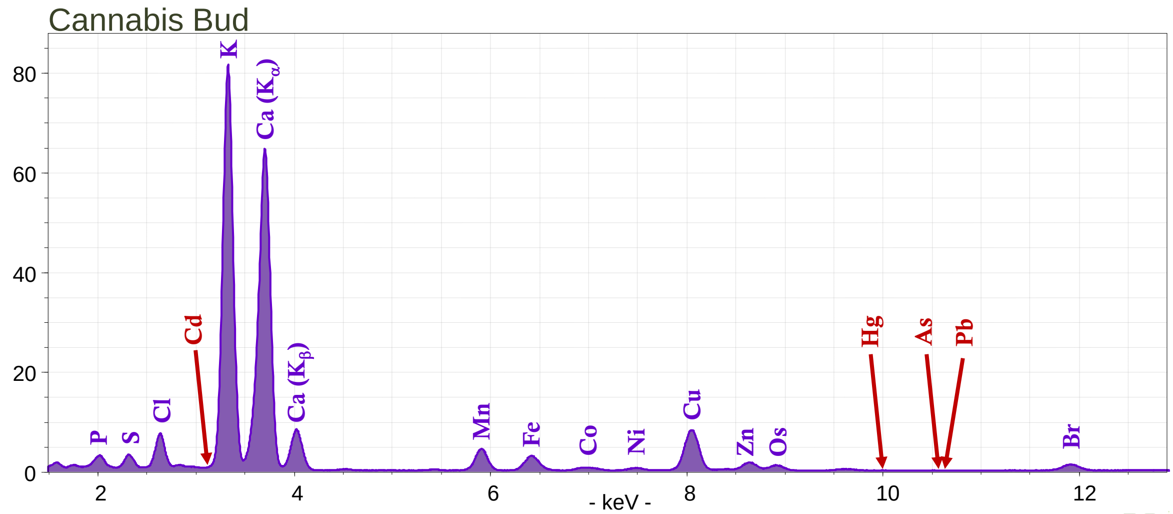
Quantitative Elemental Analysis



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Quantitative Elemental Analysis

- QC Testing for Soil, Fertilizers and Water During Cultivation
- Better Understand Nutrient Uptake by Plants
- Identify of Heavy Metal Contamination

Hemp Extract Based Product – Sourced out of China

Mercury concentration higher than acceptable limits →

Element	USP Limits (ppm)*	Measured Conc.(ppm)	Limits of Detection (ppm)
Cr (Chromium)	2.5	ND	0.013
Mn		0.191	0.011
Fe (Iron)		0.169	0.009
Ni (Nickel)	0.15	ND	0.006
Cu (Copper)	10	0.123	0.005
Zn		0.31	0.005
Ga		5	0.004
As (Arsenic)	0.15	ND	0.003
Rb		0.907	0.004
Sr		0.41	0.004
Hg (Mercury)	**0.15**	**0.203**	0.005
Pb (Lead)	0.5	ND	0.004

* Limits established for administration of pharmaceuticals by inhalation – United States Pharmacopeia USP 232/233

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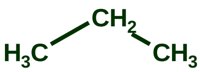
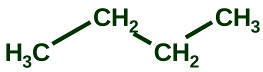
Volatile Organic Compounds (VOCs)

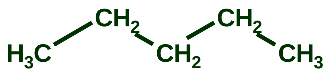
Propane



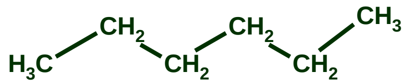
n-Butane



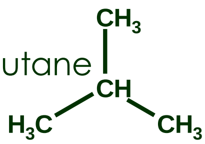
Pentane



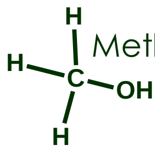
Hexane



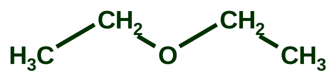
iso-Butane



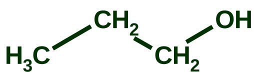
Methanol

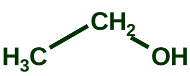


Diethyl Ether

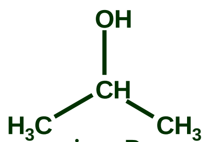


1-Propanol





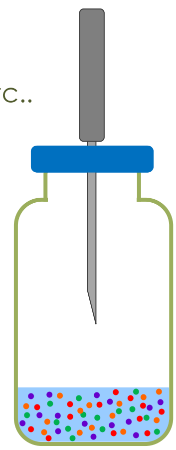
Ethanol



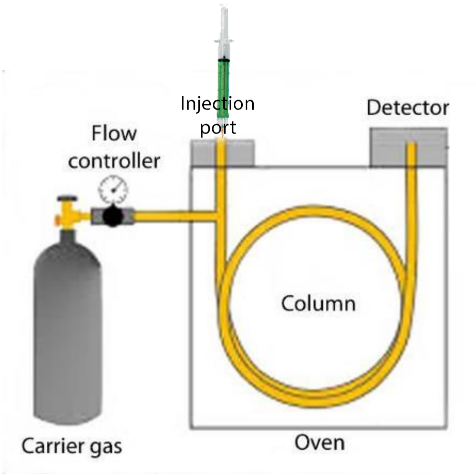
iso-Propanol

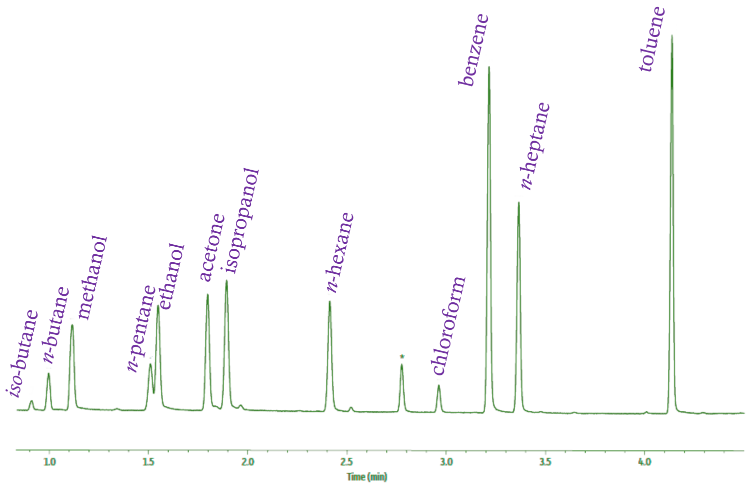
Headspace Gas Chromatography

- **Measurement of Volatile Organic Compounds (VOCs)**
  - Measure residual solvents from cannabis extractions
    - Includes common extraction solvents: butane, propane, ethanol, etc..
  - Vial is heated to volatilize organic compounds
  - Sample is collected from the headspace above the bulk
  - Sample is injected for Gas Chromatographic (GC) analysis



Headspace Gas Chromatography: VOCs





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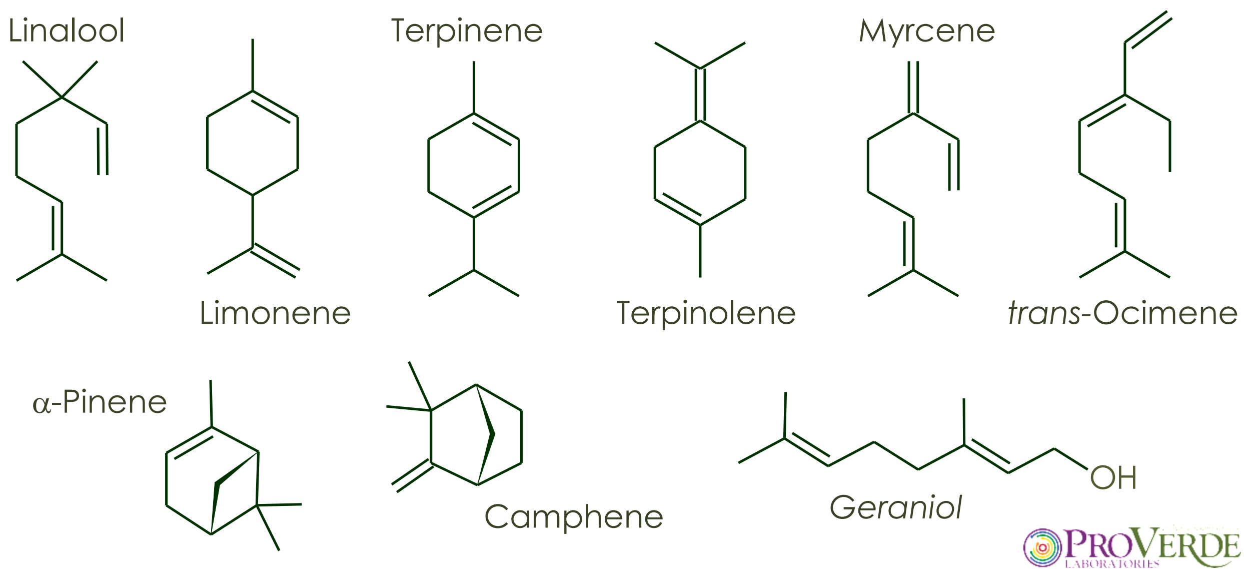
Terpenes



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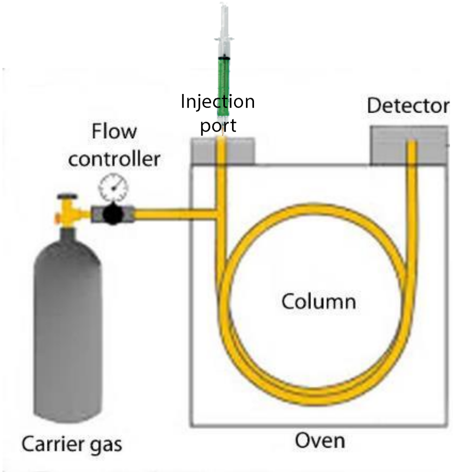
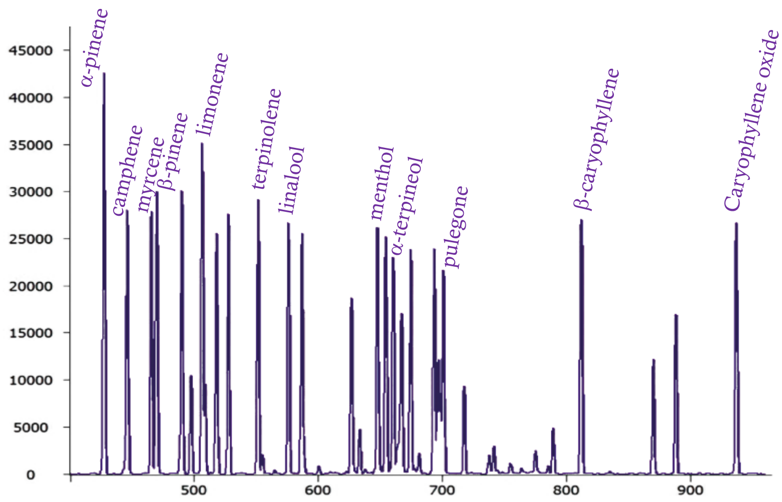
Gas Chromatography: Terpenes





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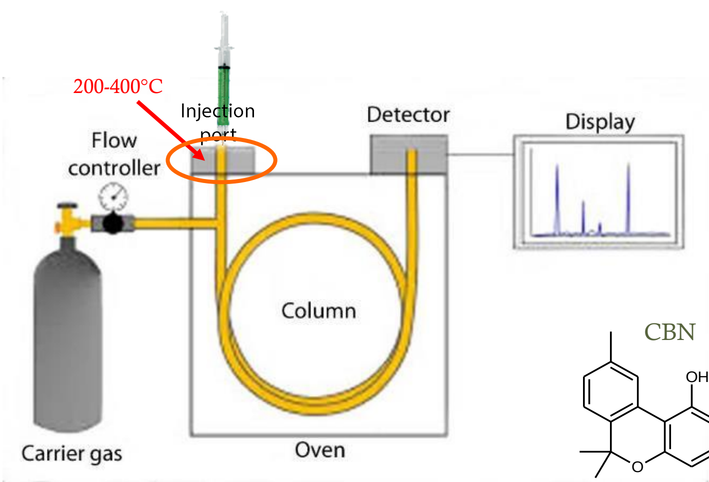
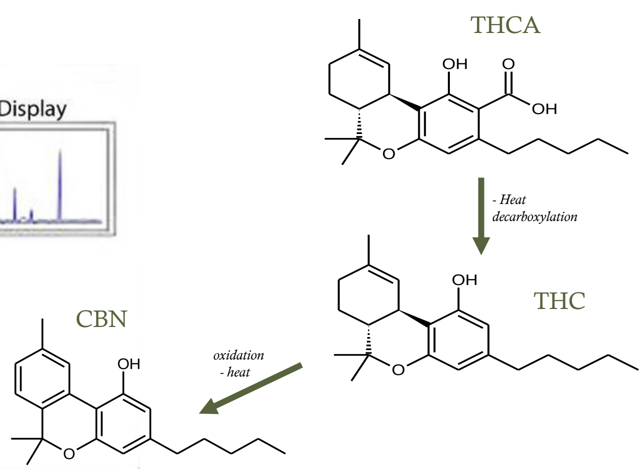
Gas Chromatography: Cannabinoids





Liquid Chromatography

- **High Performance Liquid Chromatography (HPLC)**
  - Maintains the quantitative information of the acid and neutral cannabinoids

- **UltraPerformance Liquid Chromatography (UPLC)**
  - Ultra High Pressure Liquid Chromatography (UHPLC)
  - Faster and more efficient than HPLC

Both methodologies use organic solvents to achieve the separation and quantitation of analytes

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Convergence Chromatography

- **UltraPerformance Convergence Chromatography System (UPC²)**
- **Based on the theory of Supercritical Fluid Chromatography (SFC)**
  - Uses liquid CO_2 as the primary mobile phase
- **Reduces the hazardous waste generated relative to conventional liquid chromatography**
- **Captures quantitative information on both acid and neutral (decarboxylated) form of the cannabinoids**
- **Amenable to non-polar solvents, ideal for analysis of analytes in lipid-rich matrices**

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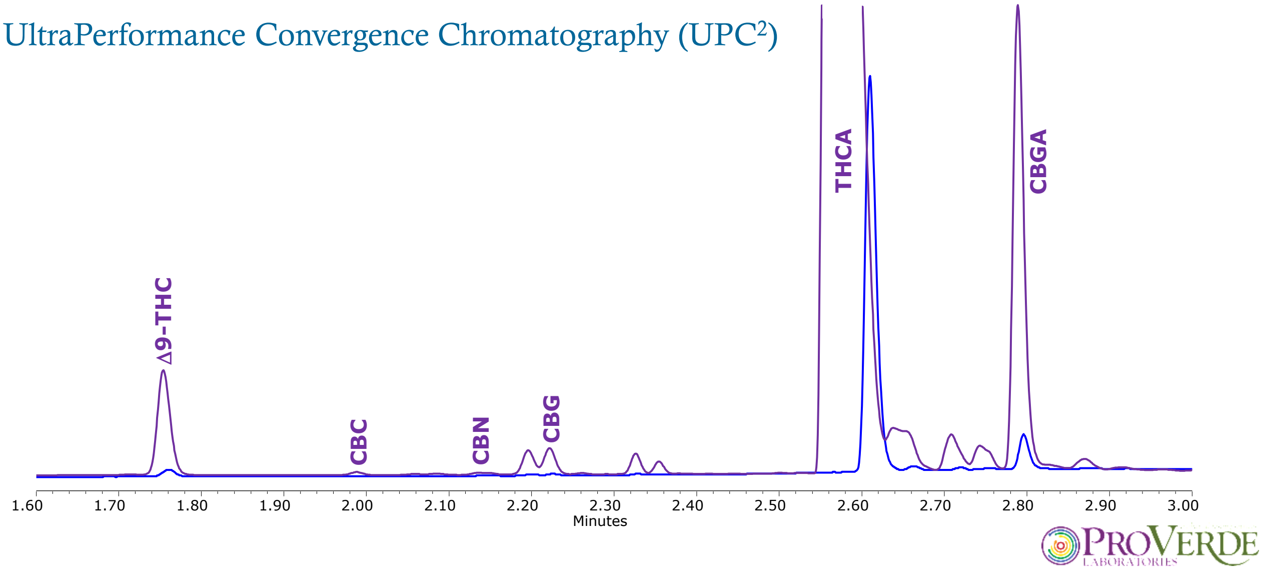
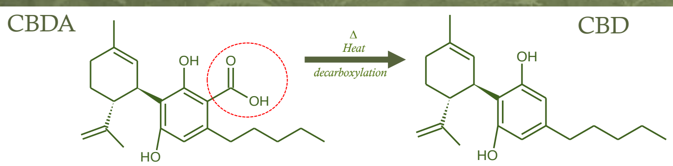
Analysis of Cannabis Flower

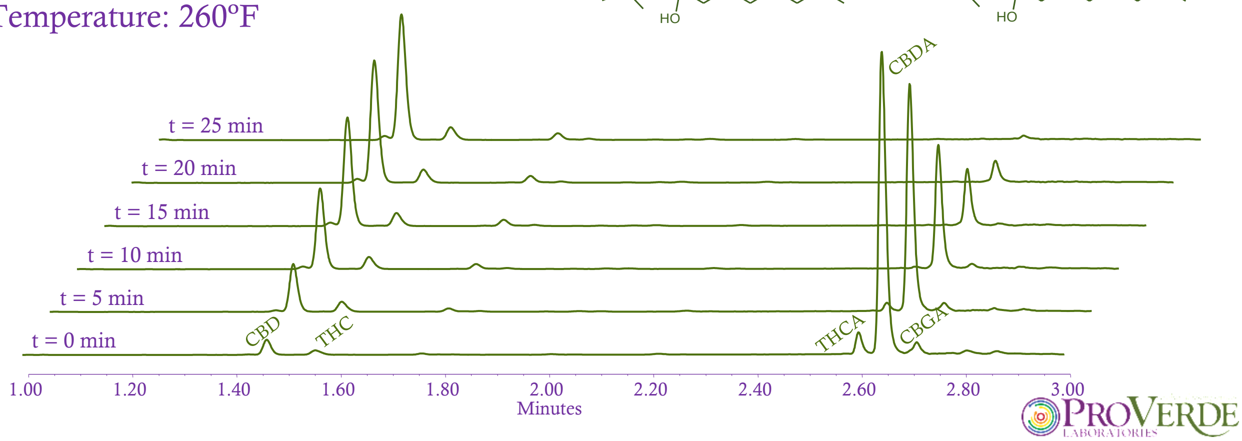
UltraPerformance Convergence Chromatography (UPC^2)



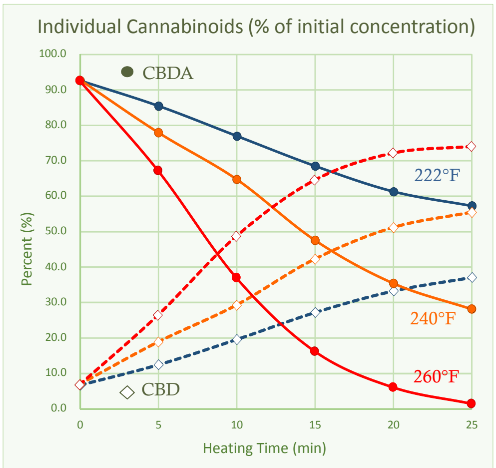
Decarboxylation

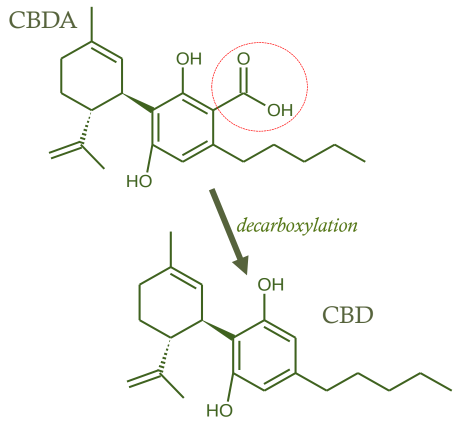


Temperature: 260°F



Decarboxylation





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Audience Poll

Which United States President was NOT a hemp farmer?

- ☐ George Washington
- ☐ Thomas Jefferson
- ☐ James Buchanan
- ☐ James Madison

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Marijuana Infused Products

- **Marijuana Infused Products (MIPs)**
  - Becoming increasingly important to the industry
  - Provides delivery formats for patients that do not want to smoke cannabis
  - Some states allow, by regulation, only derivative products to be available

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Cannabis Extractions

- **Supercritical Fluid Extractions (SFE) using liquid CO_2**
  - Safest Extraction Option: Non-toxic, non-flammable, environmentally neutral
  - Maintains terpene-rich extract profile
  - Extract can be used as the basis for many products

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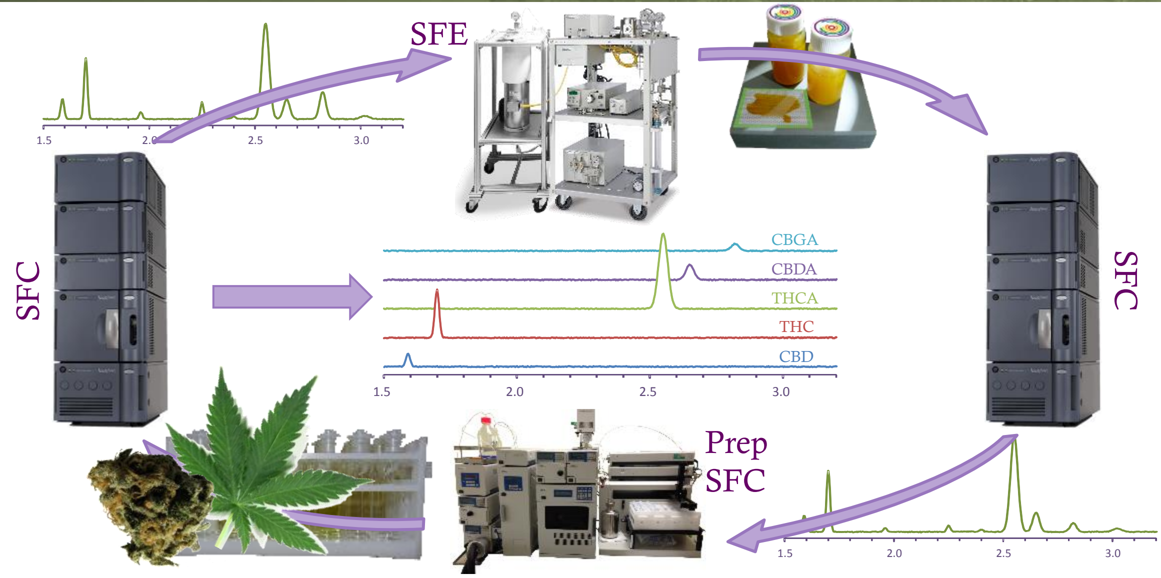
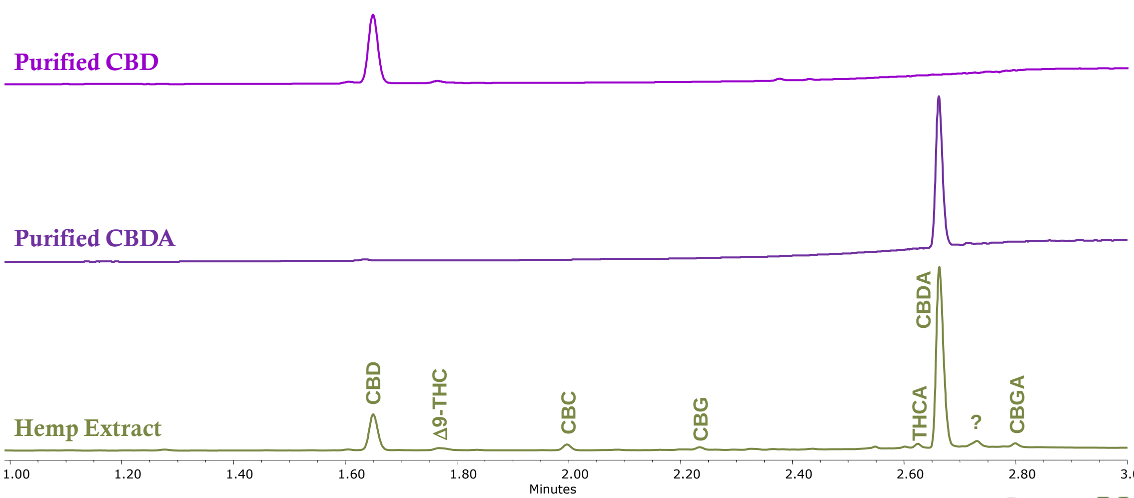
SFX Work Flow



Purification of Individual Cannabinoids



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Summary

- **Analytical chemistry will play a key role in the expanding cannabis industry, with a primary focus on ensuring patient/consumer safety**
- **The complexity of cannabis, as a natural product, with the potential for a variety of contaminants provides a number of analytical challenges that requires multiple analytical techniques to understand more fully**
- **The current trends for increased acceptance of cannabis as a legitimate industry provides the opportunity for the application of current analytical technologies to address these challenges**

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References for Additional Information

- ***Chemistry and Analysis of Phytocannabinoids and Other Cannabis Constituents***, Rudolf Brenneisen, Marijuana and the Cannabinoids (Chapter 2), **2007**, pp 17-49, ISBN 978-1-58829-456-2.
- ***Taming THC: Potential Cannabis Synergy and Phytocannabinoid-Terpenoid Entourage Effects***, Ethan Russo, British Journal of Pharmacology, 2011, **163**, 1344-1364.
- ***Non-Psychotropic Plant Cannabinoids: New Therapeutic Opportunities from an Ancient Herb***, Angelo Izzo, et al., Trends in Pharmacological Sciences**, 2009**, 30(10), 515-527.
- ***Naturally Occurring and Related Synthetic Cannabinoids and their Potential Therapeutic Applications***, Mahmoud Elsohly, et al., Recent Patents on CNS Drug Discovery, **2009**, 4, 112-136.
- ***A Fast, Simple FET Headspace GC-FID Technique for Determining Residual Solvents in Cannabis Concentrates***, Corby Hilliard, *et al*., Restek Application Note, **www.restek.com**.

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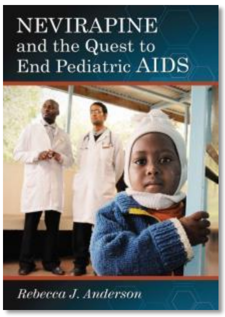
Patricia Simpson, Director of Academic Advising and Career Services, University of Illinois Urbana-Champaign



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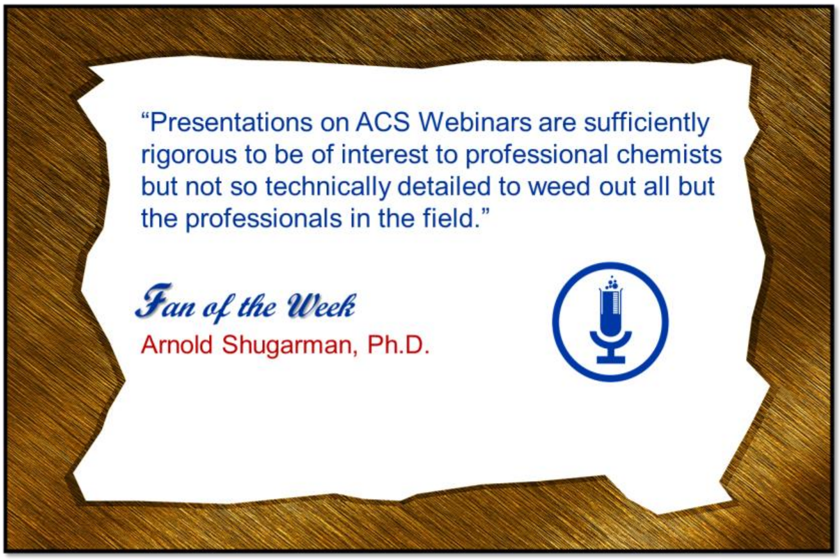

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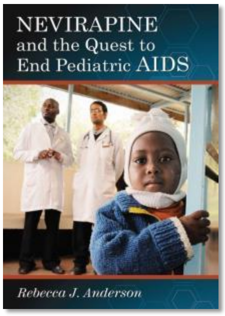
Patricia Simpson, Director of Academic Advising and Career Services, University of Illinois Urbana-Champaign



Thursday, November 20, 2014

"Optimizing Potency for Nevirapine: The Drug that Saved Children from AIDS "

Dr. Rebecca Anderson, Freelance Medical Writer and Author

Dr. Joseph Fortunak, Professor of Chemistry, Howard University

Contact ACS Webinars ® at acswebinars@acs.org

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