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Note from the CEO

The Cannabis Industry's Strong Need for a Universal Symbol

A SLIGHTLY CONTROVERSIAL topic emerging in the cannabis industry is the need for a universal symbol to be placed on cannabis and hemp products. This symbol would be used to identify products containing tetrahydrocannabinol (THC) that are over the regulated limit of 0.03%. In one of our feature articles this month, Dr. David L. Nathan and Eli Nathan delve into the need for an International Intoxicating Cannabis Product Symbol (IICPS). In 2019, while working with Doctors for Cannabis Regulation and other stakeholders Dr. Nathan proposed the Universal Cannabis Product Symbol (UCPS). ASTM International and the authors of this article co-designed a modified version of the UCPS, which was then renamed the IICPS. ASTM was fervently involved in an approval process that would make the IICPS the only cannabis product symbol to be designated as an internationally recognized consensus standard. In the US, no cannabis product symbol has been met with approval by more than one or two legalized states. This poses a serious issue of public safety for regulators, industry stakeholders, consumers, medical professionals, patients, and the general public. Dr. Nathan and Eli Nathan explain that a universal symbol for cannabis products is a safe and smart decision to move the industry forward and help protect cannabis users.

In this issue we also explore what is found in a vape in our "Extraction Science" column by Lo Friesen, which is part I of a two-part series on vapes. Our other feature article written by Samuel Burgner investigates how poor environmental control systems can lead to one of the biggest complications in commercial cultivation: pest infestations. The "Cannabis Analysis" column by Brian C. Smith continues an explanation on the importance of Beer's Law. Patricia Atkins also continues her series looking at gas chromatography instrumentation in her "Navigating the Lab" column. Last but not least, in "Cannabis Crossroads" Josh Crossney spotlights International Women's Day and Women's History Month by highlighting some incredible female speakers presenting at this year's 2022 Cannabis Science Conference West taking place May 18-20 in Long Beach, California.

We hope that you enjoy the April 2022 issue of *Cannabis Science and Technology*!

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How can we address the pest problems created in commercial cannabis cultivation facilities when environmental control systems are improperly designed or implemented?



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A universal symbol for cannabis products is essential to the protection of public health and safety. Here, we explain why and propose a symbol that is already in use in some areas.

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By Erin McEvoy

With five guiding objectives, the commission will reportedly consider the UK's cannabis industry's entire supply chain

For more on this story, please visit:
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By Erin McEvoy

RECENTLY, A CANNABIS dispensary, MediThrive, and a dozen cannabis brands in California announced a joint effort supporting aid in Ukraine. Now, more cannabis companies have followed suit. Helmand Valley Growers Company (HVGC) recently announced a pledge to donate their profits to World Central Kitchen until the end of April. Lime Cannabis Co., a cannabis manufacturer in California, said they will donate a portion of their sales to Hope for Ukraine in March. To read more visit: www.cannabissciencetech.com/news.

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Separation of Eight Cannabinoids

With the recent legalization of both medicinal and recreational marijuana in the United States, analysis of individual cannabinoids has captured the public's interest at a new level. As such, many new cannabis products are now available, i.e., edibles, vaporizers, and extracts to name a few. The increased marketability of the product has incited consumers to take a greater interest in the quality and craft ability of the products being sold. Through the quantification of individual cannabinoids, the consumer can make an informed decision about the possible effects they could expect from the products they purchase. Therefore, the need for accurate, robust, and affordable analysis tools are of the utmost importance.

With health, safety, and edibles dosing as the primary motivation, Hamilton Company developed an HPLC method that isolates eight major cannabinoids. The HxSil C18 (3 μ m) column provides an accurate, cost effective, and robust solution that can be used in any HPLC system.

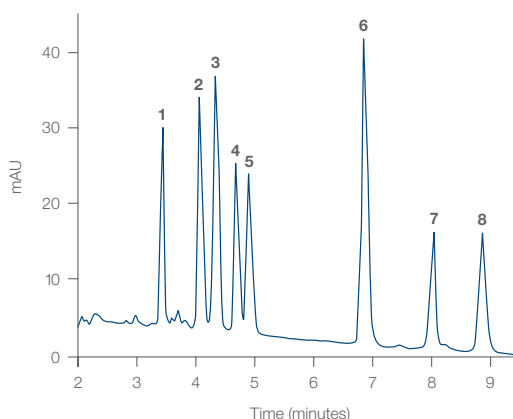
Column Information

Packing Material	HxSil, 3 μ m
Part Number	79641

Chromatographic Conditions

Gradient	0–10 min, 78–92% B 10–15 min, 78% B
Temperature	Ambient
Injection Volume	5 μ L
Detection	UV at 230
Dimensions	150 x 4.6 mm
Eluent A	20 mM NH_4COOH pH 3.5
Eluent B	Acetonitrile
Flow Rate	1.0 mL/min

Separation of Eight Cannabinoids



Compounds:

- | | |
|-------------------------------|--|
| 1: Cannabidiol (CBD) | 5: Cannabigerol (CBG) |
| 2: Cannabidiol (CBD) | 6: Cannabinol (CBN) |
| 3: Cannabidiolic Acid (CBDA) | 7: Δ -9-Tetrahydrocannabinol (Δ -9-THC) |
| 4: Cannabigerolic Acid (CBGA) | 8: Δ -9-Tetrahydrocannabinolic Acid (Δ -9-THCA) |

Author: Adam L. Moore, PhD, Hamilton Company

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Beer's Law, Part II: *Physical Basis and Derivation*

By **Brian C. Smith**

In my last column, I introduced Beer's Law, which allows high performance liquid chromatography (HPLC) and infrared spectroscopy to be used to measure potency in cannabis samples. In this column, I establish the physical basis of Beer's Law and derive it from first principles. I wrap up with a discussion of how the assumptions made in the derivation affect Beer's Law experiments.

Review

Beer's Law allows spectroscopy to be quantitative because it relates the amount of light absorbed by a sample to the concentration of chemical species in that sample (1). From last time, Beer's Law has the form of **Equation 1** (1):

$$A = \epsilon LC \quad [1]$$

where A is the absorbance; ϵ is the absorptivity; L is the pathlength; and C is the concentration.

Spectroscopy is the study of the interaction of light with matter (2), so to understand Beer's Law at a fundamental physical level, we need to think about light and how it interacts with molecules.

Light is properly called electromagnetic radiation because it consists of electric and magnetic waves undulating in mutually perpendicular planes (2). Although technically the term "light" is often used to refer to the electromagnetic radiation we can see with our eyes, I will be lazy and use it to refer to all electromagnetic radiation. Light is a mysterious devil

since depending on what phenomenon of light is being measured it can be thought of as a wave or particle (3). For the purposes of this column, we will think of light as a particle. A particle of light is called a *photon*, like the photon torpedoes in *Star Trek*. A photon of light has energy but no mass, and its energy is given by **Equation 2** (3):

$$E_p = hcW \quad [2]$$

where E_p is the energy of a photon; h is Planck's constant; c is the speed of light; and W is wavenumber.

Briefly, the wavenumber W of light is $1/\text{wavelength}$, and if wavelength is measured in cm, then W has units of cm^{-1} . The x -axis of spectra are often plotted in wavelength or wavenumber units. An example of the mid-infrared spectrum of a cannabis bud is seen in **Figure 1**.

Note that the x -axis of **Figure 1** is in wavenumber units, and that the y -axis is in absorbance. Note that when plotted in absorbance the peaks point up, and the tops of the peaks denote wavenumbers where a significant amount of light is absorbed. The absorbance here is the same as the A in Equation 1 above, and yes, the peak heights and areas in **Figure 1** can be used to determine the potency of cannabis plant material (4-6).

When Photons and Molecules Collide

When thinking of light as a photon, we can picture its interaction with molecules as that of a collision. **Figure 2**

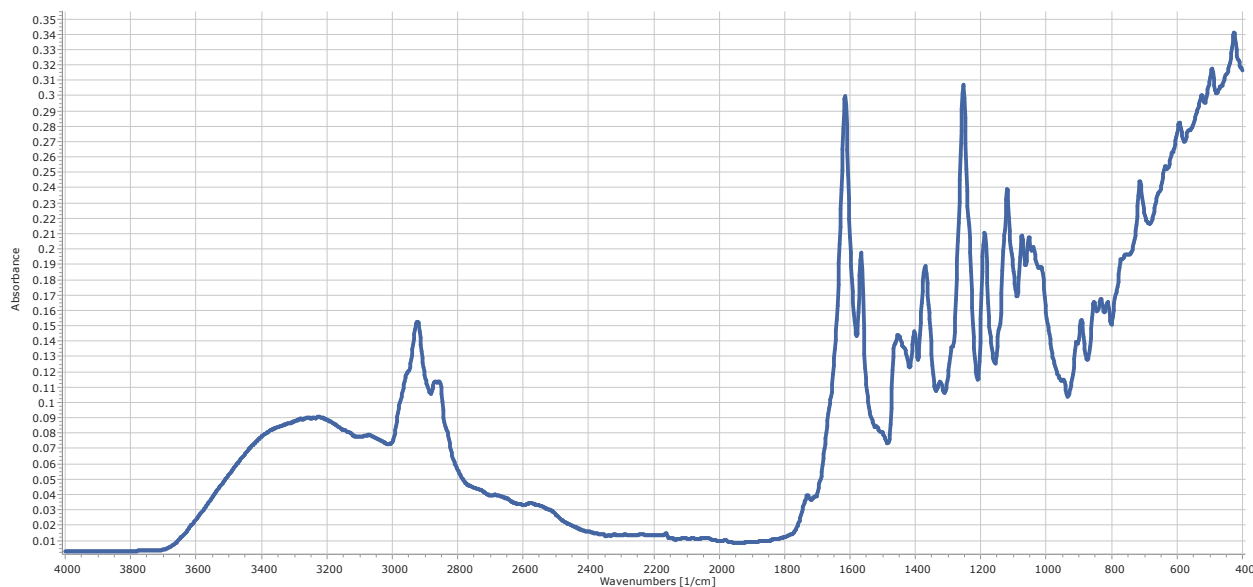
illustrates a photon about to collide with a methane molecule.

For simplicity's sake, I have represented the methane molecule as a simple sphere. However, methane has a tetrahedral structure (7).

Physicists define different types of collisions based on what happens to the energy in the photon as a result of the collision (3). In **Figure 2** before colliding with the methane molecule the photon has energy E_p , and to make life simple we will assume the methane molecule is at rest and has no energy. In what is called an *elastic collision*, no energy is exchanged between the methane molecule and the photon, and the photon leaves the collision with energy E_p and the methane molecule is still at rest. Note in **Figure 2** that the direction of the photon does change. Elastic collisions between photons and molecules give rise to a phenomenon called *Rayleigh scattering* (8). The intensity of Rayleigh scattering is proportional to the fourth power of the wavenumber, or W^4 , of the light being scattered. Rayleigh scattering is why the sky is blue; blue visible light is the highest wavenumber light we can see and is scattered with more intensity than all other visible light. Although Rayleigh scattering gives us a beautiful sky, it does not provide us with much chemical information.

Figure 3 illustrates that is called an *inelastic collision* between a molecule and a photon.

Figure 1: The mid-infrared spectrum of a cannabis bud. The x-axis is in wavenumber (cm^{-1}) units, while the y-axis is in absorbance units.



During an inelastic collision the photon changes direction and loses some energy to the methane molecule, exciting it vibrationally. The amount of vibrational energy obtained by the methane molecule, E_v , must be equal to the amount of energy lost by the photon to maintain conservation of energy. After the collision the total amount of energy in the system is the sum of the energies of the photon and molecule, E_{total} , such as seen in **Equation 3**:

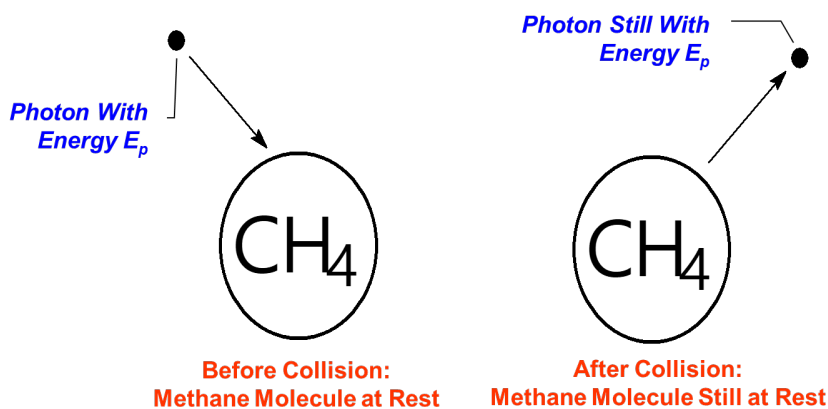
$$E_{\text{total}} = E_p + E_v \quad [3]$$

And the amount of energy the photon now has is given by **Equation 4**:

$$E_p = E_{\text{total}} - E_v \quad [4]$$

The collision of the photon and molecule exciting the molecule vibrationally is analogous to hitting a bell with a hammer, where the photon is the hammer, and the methane molecule is

Figure 2: A photon undergoing an elastic collision with a methane molecule. Note that the only change is the direction of the photon.



the bell. Some of the hammer's energy is transferred to the methane molecule causing it to vibrate or "ring."

The inelastic scattering of photons by molecules is called *Raman scattering* (9). Analysis of Raman scattered photons provides chemical structural information about molecules, like how infrared spectroscopy provides

this information. Raman spectroscopy is a well-developed field of chemical analysis (9) and has been used to analyze cannabis plant material (10-12).

Figure 4 shows what happens when all the energy in a photon-molecule collision is transferred from the photon to the molecule. This is called a *totally inelastic collision*.

Figure 3: An example of an inelastic collision between a photon and a methane molecule. Note that the photon leaves the collision having changed direction and with less energy, $E_p - E_v$, than before. Also, the methane molecule is now vibrating with energy E_v .

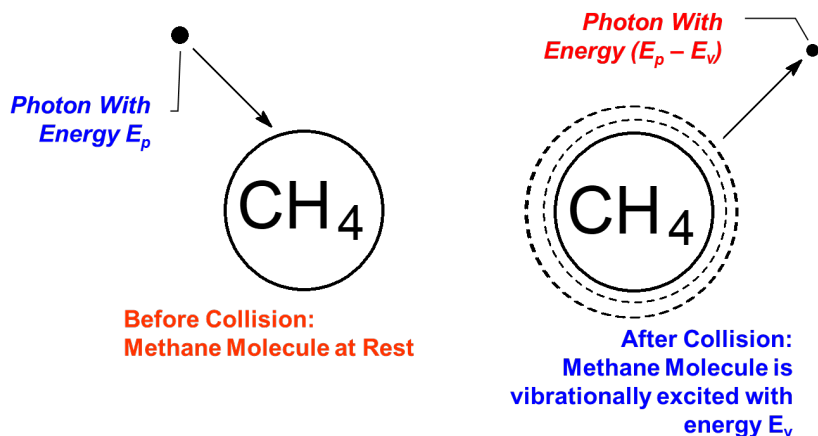
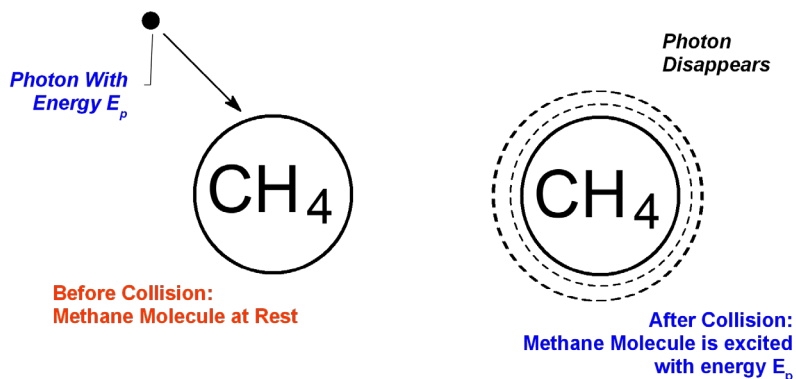


Figure 4: An example of a totally inelastic collision between a photon and a methane molecule. Note that since all the photon energy is absorbed by the methane it now has energy E_p , and that the photon ceases to exist.



Again, since the Law of Conservation of Energy must be followed, and all the photon's energy is deposited into the methane, the final energy of the methane molecule is then E_p . As a result of a totally inelastic collision, the methane molecule can vibrate similar to the result of an inelastic collision. Since the methane molecule absorbs all the photon's energy, inelastic collisions give rise to a phenomenon known as *absorbance*—yes, the A in Beer's Law in Equation 1 above.

The Derivation of Beer's Law

When a beam of photons travels through a sample of matter, let's say a gas or liquid to make things simple, how many photon-molecule collisions occur? Intuitively, the more photons there are passing through a sample the more collisions there will be, and the number of photons a light beam contains is simply its intensity (I). Similarly, the more molecules there are in a sample the more photon-molecule collisions there will be.

The number of molecules in a sample is determined by its concentration (C).

How do we quantify these ideas? Consider **Figure 5**, which should look familiar as it was in the last column as well (1). This is an example of an experimental setup commonly used in Beer's Law experiments.

In Figure 5, λ is the wavelength of light passing through the sample; I_0 is the measured light intensity before the light beam enters the sample; I is the measured light intensity after the light beam has exited the sample; L is the path-length or sample thickness; and dL is an infinitesimally thin slab of the sample.

In Figure 5, the light beam of single wavelength λ and intensity I_0 impinges perpendicular to the face of a sample. The light beam leaves the sample at the same wavelength λ but with intensity I . Light intensity has been lost by collisions between photons and molecules. L is the pathlength or sample thickness, and dL is an infinitesimally thin slab of the sample. As stated above, the number of collisions depends upon the number of photons, the number of molecules, and the pathlength—the thicker the sample, the higher the probability a photon will encounter a molecule. If we let $-dI$ represent the light intensity lost by photon-molecule collisions, we can write proportionality **Equation 5** as such:

$$-dI \propto I C dL \quad [5]$$

where dI is the amount of light lost to all scattering; I is the light intensity in slab dL ; C is the concentration; and dL is the infinitesimally thin slab of sample.

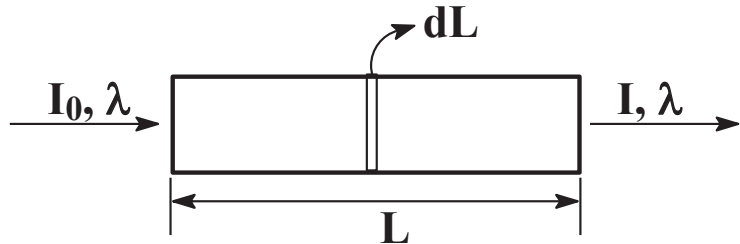
Proportionality, Equation 5 simply shows that the amount of light lost depends on the total number of photon-molecule collisions, which depends upon the number of photons I , the concentration of molecules C , and the thickness of our sample slab dL . Now, remember that Beer's Law deals with absorbance, and

that absorbance is due to totally inelastic collisions only. So, to measure the total absorbance we would need to know the number of totally inelastic collisions, or in other words what fraction of photon-molecule collisions are totally inelastic. This fraction is given by the absorptivity, ϵ , yes, the same absorptivity that we discussed last time (1) and that appears in Equation 1 above. By inserting ϵ into proportionality Equation 5, we obtain **Equation 6**, which gives the amount of light intensity lost due to totally inelastic collisions, or absorbance, as such:

$$-dI = \epsilon I C dL \quad [6]$$

where dI is the amount of light lost in totally inelastic collisions; ϵ is the ab-

Figure 5: A typical experimental setup for using Beer's Law to perform quantitative spectroscopy on a sample.



sorptivity; I is the light intensity in slab dL ; C is the concentration; and dL is the infinitesimally thin slab of sample.

At this point in the derivation, we need to get from Equation 6 to the final form of Beer's Law. This necessitates using calculus to integrate both sides of

Equation 6. I will not go into the math here—consult my book on quantitative spectroscopy for the details (3). Long story short we end up with **Equation 7**, which is Beer's Law:

$$A = \epsilon LC \quad [7]$$

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where A is the absorbance; ϵ is the absorptivity; L is the pathlength; and C is the concentration.

Assumptions Behind Beer's Law

In the derivation of Beer's Law several assumptions must be made, which effects how quantitative spectroscopy experiments are performed (3). These assumptions are:

1. The light beam contains only 1 wavelength, which is wavelength λ . We normally use a light beam containing many wavelengths in it to measure spectra. Fortunately, using light beams with many wavelengths in them generally presents no problems.
2. The sample is homogeneous. Remember we started with a slab dL , of the sample. The assumption in the derivation is that all such slabs dL are identical. This means we are assuming that all parts of the sample are the same, and that the concentration of the absorbing species is the same everywhere in the sample as well. We are also assuming that the physical condition, things such as temperature and pressure, is the same in all portions of the sample. Insuring sample homogeneity is normally not a problem for gases and liquids, which can be stirred and mixed easily. However, for a solid such as a cannabis bud, even one that has been ground, most certainly the sample is not homogeneous. That is why, for example, when using infrared spectroscopy to determine potency in dried, ground cannabis multiple portions of the sample are scanned, and the results are averaged to obtain representative data on the sample (5-6).
3. Our derivation of Beer's Law

assumes that all loss of photons in the sample is from totally inelastic collisions. Commercial spectrometers cannot distinguish between light lost by absorbance, Rayleigh scattering, or Raman scattering. Additionally, there are light losses because of reflections and absorbance by sample cell materials, contaminants on sample cell windows absorbing, suspended particles of dirt and dust that can scatter photons, and contaminant chemical species that can absorb. Since the spectrometer can't tell the difference between all these sources of light loss, one needs to control or eliminate as many of these sources as possible. For sample cell contributions, one can scan a "background" scan of an empty cell, and if this contribution is the same from background to sample it is ok. Suspended crud should be filtered from gas and liquid samples, not so easy for solids. Lastly, make sure your sample does not contain impurities that can interfere with the measurement of the absorbance of your chemical species of interest.

Conclusion

Using the idea of photon-molecule collisions, we showed how totally inelastic collisions lead to light absorbance. Then, using the number of photons and molecules present, we wrote a proportionality which gave us the total number

of photon-molecule collisions. Next, by inserting the absorptivity, which is the fraction of collisions that are totally inelastic we derived Beer's Law. Lastly, the assumptions made in the derivation and how they affect real world experiments were discussed.

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ABOUT THE COLUMNIST

BRIAN C. SMITH, PHD, is Founder, CEO, and Chief Technical Officer of Big Sur Scientific. He is the inventor of the BSS series of patented mid-infrared based cannabis analyzers. Dr. Smith has done pioneering research and published numerous peer-reviewed papers on the application of mid-infrared spectroscopy to cannabis analysis, and sits on the editorial board of *Cannabis Science and Technology*®. He has worked as a laboratory director for a cannabis extractor, as an analytical chemist for Waters Associates and PerkinElmer, and as an analytical instrument salesperson. He has more than 30 years of experience in chemical analysis and has written three books on the subject. Dr. Smith earned his PhD on physical chemistry from Dartmouth College. Direct correspondence to: brian@bigsurscientific.com

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What's in a Vape, Part I

By **Lo Friesen**

Since 2019's "vape crisis," cannabis and nicotine vapes have been under a rollercoaster of scrutiny, and with good reason. In this two-part series, we will review the history of vape products and their obstacles, what to look for in vape cartridge hardware, and what operators should be aware of as producers of vape products.

Vaping is a choice made for many reasons such as health, discretion, flavor, and versatility. The first vaporizer was patented in 1930, but it wasn't until 2003 that nicotine e-cigarette products became commercially available in China. In 2006, e-cigarettes made their way to Europe and the US when e-cigarette companies and the World Health Organization (WHO) both declared e-cigarettes a smoking cessation aid and marketed them as such. However, in 2008 the WHO rescinded their stance and marketing, no longer proclaiming e-cigarettes as a smoking cessation aid (1). The current concern is the potential toxins that can be found in e-cigarettes along with the flavors and marketing that is attracting youth to nicotine.

Herbal vaporizers have been popular for cannabis flower since the late 1990s, after the invention of the Volcano. However, cannabis extract vaporizer devices did not become readily available until sometime between 2010–2013. Manufacturers, consumers, and governing bodies believed the transition to vaping cannabis oil could be safer than combustion because of the ability to control the temperature at which the extract is vaped thereby limiting combustion. Research demonstrates that vaping pure cannabis extract is safer than smoking cannabis flowers (2). Vaporizing cannabis extract eliminates inhalation of combusted

fibrous plant material, which is carcinogenic, and limits exposure to potentially toxic compounds. In addition, cannabis extract can be vaped at a lower temperature than smoking occurs. Extraction concentrates the desirable components of the plant matrix, mainly cannabinoids, terpenes, and terpenoids. Inhalable cannabis products, such as vapes, offer consumers immediate relief and predictable effects as opposed to the delayed and unpredictable effects of ingestible cannabis products. This promotes easy self-titrating, which benefits all types of consumers. For these reasons, it's clear that vaping pure cannabis extract is safer than smoking and may be a better alternative for many users.

Given the history of nicotine vapes, the cannabis industry had an opportunity to limit the potential for toxic chemicals to be used in production. While the cannabis industry is strictly regulated, regulatory agencies are not sufficiently resourced and are unfamiliar with all that goes into producing an extract and a cannabis vapor product. While some regulations are in place to protect consumers, such as restricting pesticide use and testing to ensure heavy metal levels are below toxic limits, many states did not limit additives to cannabis extracts until after the "vape crisis" in 2019. It's vital for consumers and industry members to advocate for safe vape products with minimal ingredients.

Responsible manufacturing is in the hands of the hardware suppliers and cannabis manufacturers producing vape cartridges and extracts. Margins are an important part of business success, especially in a time where cannabis is becoming more of a commodity. This incentivizes operators to source low cost vape hardware. However, there is now evidence to show that there is a wide range of vape cartridge quality and safety. This variety in quality results in a range of potential presence of harmful heavy metals in the vapor (3). While many states require heavy metal testing of the final extract, none require testing of product hardware or of the product after it has spent time in the hardware. Because of this, conscious vape companies are moving towards higher cost hardware and higher quality hardware to ensure their product is safe, thus providing a positive experience for the consumer. Because of their market growth, vape cartridges will continue to become better, safer, and more popular.

In part II of this series, we will review the methods for vape extract production and define the wide array of extract types.

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ABOUT THE COLUMNIST

LO FRIESEN is the founder, CEO, and Chief Extractor of Heylo. With a background in chemistry and clinical research, Lo

was inspired to explore cannabis as a medicine and to enter the emerging industry. She joined Eden Labs, a leading CO₂ extraction equipment manufacturer to support and expand a Research and Development department. There she managed the development of their latest and greatest CO₂ extraction system. In 2017, after working with Eden Labs and another cannabis processor, Lo launched Heylo with a mission to help people get more out of life with cannabis.



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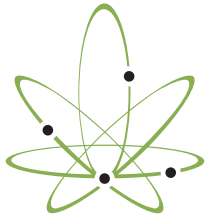
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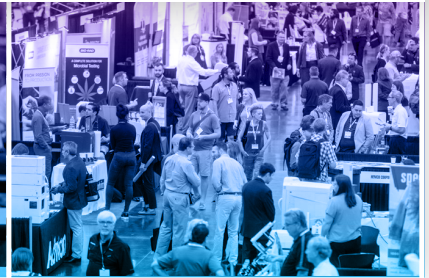
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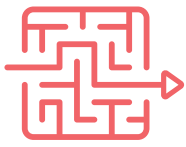
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Looking with Light: *Understanding Gas Chromatography, Part III: Columns and Resolution*

By **Patricia Atkins**

Gas chromatography (GC) resolution and analyses depend on the functionality of the chromatography phases. In the past columns, we looked at gases and the choices surrounding the gas phase. In this edition of "Navigating the Labyrinth," we will seek to understand the functioning and chemistry of GC columns and how to change and manipulate the resolution equation and column chemistry to maximize our own analyses. We will take a deeper look into the chemistry, physics, and methodology of GC columns to see what changes can be made to increase resolution, efficiency, capacity, and change retention.

The first thing most analysts decide upon when developing a gas chromatography (GC) or gas chromatography-mass spectrometry (GC-MS) method is the chromatography column that will be used for analysis. There are two basic configurations for columns: packed or capillary columns (**Figure 1**). The earliest GC columns were packed columns composed of either glass or stainless-steel loops or coils between 1 m and more than 12 m in length with diameters in the mm range, which are filled with a stationary phase or packing material.

In the early days of GC, many analysts had to load or pack their columns with their selected solid phases. The packing or phase can be a solid, liquid, or mix of materials to facilitate chromatography. Packing materials are broken down into either coated or porous particles. Coated particles have an internal structural particle made of some type of inert compound or matrix such as diatomaceous earth and are coated with the active liquid

stationary phase. Porous particles are materials like polymers or carbons (sieves, traps, and so on). Packed columns have shorter lengths than capillary columns and are very efficient at separating very volatile gases and other low-boiling compounds.

The second general type of column is a *capillary column*. The capillary column is composed of a very long tube of thin hollow silicate glass anywhere from 10–100 m long and diameters in the micron range. This small diameter and long length dramatically can increase pressure in a GC system, but produce more theoretical plates from the efficiency equations we looked at in previous columns where efficiency can be measured as a relationship between separation factor (α), column length (L), and particle size or film thickness (d_p). So, more length or a thinner film equates to more theoretical plates.

The interior of the capillary column is coated with a stationary phase composed of either a solid or a liquid material. Capillary columns are able to achieve better separation, but can

become overloaded by excess sample volumes. Several different physical configurations exist for capillary columns including some configurations that contain solid particle stationary phases instead of just liquid stationary phase.

The most common type of capillary column is the *wall coated open tubular* (WCOT) columns or the *fused silica wall coated* (FSWC) columns. The WCOT column is usually composed of a silica tube coated with a liquid stationary phase. Most modern open tubular capillary columns are FSWC columns that are extremely thin-walled silica columns with open active site surfaces on the interior of the column where stationary phase not only coats the column but bonds to active, open sites.

Specialty open tube configurations such as the *support coated open tubular* (SCOT) and the *porous layer open tubular columns* (PLOT) are a blend of solid and liquid phases and supports, in some ways similar to both capillary and packed columns. The SCOT column has a solid framework or support upon which the liquid layer coats the support

structures and the silica column. PLOT are a hybrid of an open tubular column and a packed column that contains a solid porous layer inside the column structure unlike packed columns which are completely filled or “packed” with a porous stationary phase (Figure 2).

Modes of Chromatography and Columns

There are two primary modes for chromatography: *partition* and *adsorption chromatography*. Partition or gas-liquid (GLC) chromatography occurs in the transitioning of an analyte from the gas phase to liquid phase and back to gas phase along the column (that is, partitions). GLC is found in the capillary columns with a liquid stationary phase. Adsorption or gas-solid chromatography occurs (GSC) when targets in the gas phase are absorbed into a solid material stationary phase. GSC is found in both packed columns and in the PLOT columns. The materials of the solid support structures found in packed, PLOT, and SCOT columns can be made from a variety of inert materials like diatomaceous earth coated with a liquid stationary phase. Other stationary phase particles are created from porous materials such as carbon compounds and polymers.

For capillary columns, the most common stationary phase is composed of polysiloxanes with added phenyls and functional groups to the polarity and affinity of the column for a wide variety of compounds. The least polar stationary phases are polydimethyl siloxane (PDS). The most polar phase is composed of polyethylene glycols (PEG columns, carbowax or “wax” columns) (Table I) (Figure 3). Polarity increases with the number of phenyl groups or other functional groups used to create separation (Figure 3). The amount of these functional groups in some cases translates to the column name reflecting the percentage or composition of the siloxane groups.

Figure 1: Capillary and packed column structures.

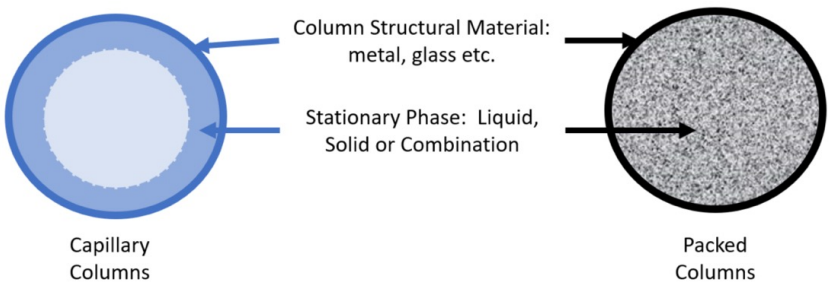


Figure 2: GC column configurations and anatomy.

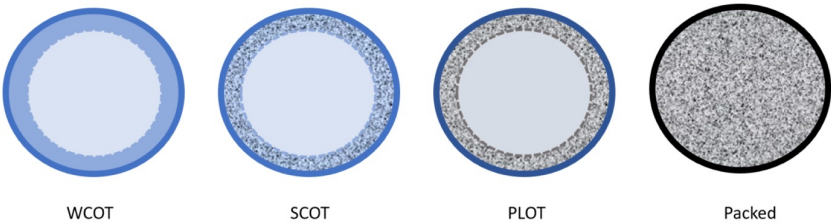


Table I: Capillary column stationary phase components and properties

Compound Group	Polarity	Dipole	H-Bonding
Polydimethyl polysiloxane (PDMS)	Low	None	None
Phenyl	Low	None	Low
Diphenyl	Low to Mid	None	Low
Cyanopropylphenyl	Mid	High	Mid
Polyethylene glycol	High	High	High

Table II lists the most commonly used capillary column phases and their naming convention, composition, and bonding characteristics. Most companies that produce columns use the same naming conventions in regard to common columns; with the first two or three letters being the company or brand with a dash followed by the composition. So, an RTX-5 is a Restek 5% DP, 95% PDS column and is equivalent in theory to another XX-5, like an Agilent StableBond SB-5. Once a stationary phase or polymer is added to coat a column, a process of cross-linking may be used to stabilize the polymer over a wide range of temperature and reduce column bleeding.

Manufacturers can also produce their own polymers and cross-linking agents, which can impact the column’s function. In all columns, there are potential active sites within the column material and open functional groups that are not deactivated fully even with crosslinking that could cause difference between different versions or brands of the same phase columns.

Dimensions and Resolution

There are a number of factors that can affect resolution including: chemistries of solute, gas phase, and stationary phase plus a number of physical parameters such as flow rate, temperature, and column length, diameter, and film thickness.

Figure 3: Common capillary column stationary phase siloxane groups and PEG (increasing polarity).

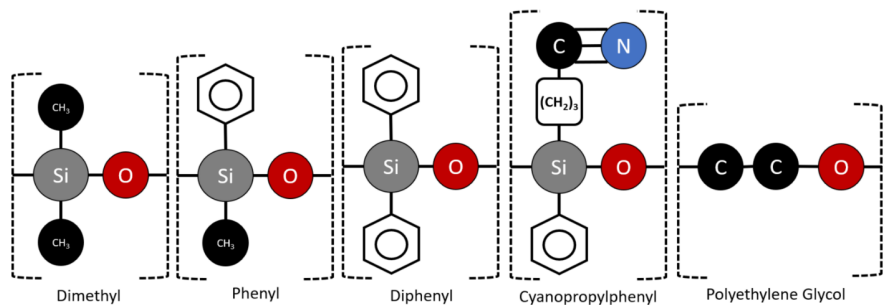


Table II: Common GC Capillary columns, composition, and properties. (Note: Some manufacturers may choose slightly different siloxane configuration compounds as part of their proprietary stationary phases.)

Column Designation	Composition	% Phenyl	Column Polarity	Separation	Example Target Analytes
XX-1	100% PDMS	—	Non-polar	Dispersion	Non-polar: Alkanes, gases, petroleum products
XX-5	95% PDMS	5% Diphenyl	Non-polar	Dispersion and induced dipole	Non-polar: Alkanes, gases, petroleum products
XX-35	65% PDMS	35% Diphenyl	Low to mid polarity	Dispersion and induced dipole	General purpose: large range, pesticides, drugs, and so forth
XX-1701	86% PDMS	14% Cyanopropylphenyl	Medium polarity	Dispersion, permanent, and induced dipole, H-bonding	General purpose: large range, pesticides, drugs, and so forth
XX-624	94% PDMS	6% Cyanopropylphenyl	Medium polarity	Dispersion, permanent dipole, and H-bonding	Polar or polarizable: VOAs, solvents
XX-Wax	100% PEG	—	Polar	Dispersion, permanent dipole, and H-bonding	Polar or polarizable: aromatics, alcohols, VOAs

Table III: Phase ratios for GC column diameters and film thickness. Green = volatile compounds; yellow = general purpose; and red = high molecular weight compounds.

Inner Diameter (d) mm	Film Thickness (df) um						
	0.1	0.3	0.5	1	2	3	5
0.1	250	100	—	—	—	—	—
0.18	450	180	90	45	30	15	9
0.25	625	250	125	63	42	21	13
0.32	800	320	160	80	53	27	16
0.53	1325	530	265	133	88	43	27

If we think back to the resolution equation discussed in previous columns on chromatography, resolution is a product of retention, separation, and efficiency. Changing or influencing any of these parameters will change resolution (**Equation 1**).

Selectivity

$$R = \left(\frac{k}{1+k} \right) \left(\frac{\alpha-1}{\alpha} \right) (1/4 \sqrt{N})$$

RetentionEfficiency

[1]

One of the first changes a chromatographer can make to a system

without changing the column is often temperature. Changes in temperature can influence the resolution equation by changing retention and selectivity. Increases in temperature change the amount of time the solute or target spends in the stationary phase, usually increasing retention times or by losing retention. Temperature increases can also influence or change the chemistry or physics of the interactions between the phases and thereby reduce selectivity. Another problem with raising temperature is that it will change flow rates of the system.

The next column variable to change is often the column length (L), which can then change resolution by altering

Table IV: Column diameter efficiency, sample capacity, and use

Inner Diameter (d) mm	Type	Use	Estimated Efficiency (N/m)	Analyte capacity (ng) max
0.53	Megabore	Headspace, P&T, on-column, packed column replacement	1000-2000	~2000
0.32	Widebore	Wide concentration ranges, complex samples, split, splitless and direct injections	2000-4000	<500
0.25	Narrowbore	Wide concentration ranges, complex samples, split, splitless and direct injections	3000-5000	<150
0.2	Narrowbore	Split mode, GC-MS	4000-6000	<70
0.18	Minibore	Split mode, GC-MS	4000-7000	<50
0.1	Microbore	Split mode, GC-MS	7000-12,000	<10
0.05	Nanobore	Split mode, GC-MS	>10,000	1 to 2

the efficiency (N). While increasing length can change efficiency and resolution, large increases in length only fractionally change the resolution. Increasing a column length by four times only increases resolution about

two times; but often comes with an exponential cost increase for that column (**Equation 2**).

$$N = \frac{1}{4} \sqrt{(L/H)} \quad [2]$$

A better way to increase retention is to decrease the column diameter (d) or alter both the film thickness and the diameter since they are interrelated. *Film thickness* (df) is a measure of the amount of stationary phase that can

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interact with the target solutes. To understand this relationship, first we must look at the distribution constant (K_D) which is the ratio of the concentration of the solute in the stationary phase versus the concentration of the solute in the mobile phase (Equation 3).

$$K_D = \frac{C_{sp}}{C_{mp}} = k\beta \quad [3]$$

This distribution constant is also equal to the capacity factor (k) multiplied by the phase ratio (β), meaning it will affect the k retention variable. The true importance and influence of k occurs when the ratio between the phases is small (<5), increases to the film thickness will then increase resolution but, when k is greater than five, then resolution decreases as film thickness increases.

The *phase ratio* is the relationship between the column inner diameter and the stationary phase film thickness, where the phase ratio is equal to the inner diameter divided by four times the film thickness (Equation 4).

$$\beta = d_i / 4 d_f \quad [4]$$

The phase ratio can help narrow down the best choice of column ID and film thickness or can help change from one column dimension to another. Each phase ratio is best suited for particular classes of compounds. Very volatile compounds do best with a phase ratio less than 100, while most other compounds fall in a phase ratio between 100 and 400. The highest boiling or molecular weight compounds will do best at phase ratios greater than 400 (Table III).

Thicker films allow for more solute capacity on the column and decreases interaction with any open sites on the tubing, but thicker films increase column bleed and reduce the operating temperature for the column.

Increasing film thickness can increase retention since peaks spend more time in the stationary phase, but they lose height and broaden. Increasing peak width and reducing peak height reduces efficiency as can be seen in the efficiency equations where large widths or shorter heights adversely affect efficiency (Table IV) (Equation 5).

$$N = 2\pi(h_p t_R/A)^2$$

$$N = 16(t_R/W_b)^2 \quad [5]$$

Final Thoughts

A number of factors surrounding the GC column can influence your chromatographic resolution depending upon which component of the resolution equation is affected. Selectivity is mostly influenced by the type of stationary phase selected. The more substituted siloxanes of the phase are, the more polar the column, and the more polar the analytes it will detect. Selectivity can also be influenced by increases in temperature but often at a loss of other variables. Efficiency is most affected by column radius and film thickness, but can be increased with increasing column length, however, often at a monetary cost. Retention can be changed by manipulating the temperature of the system or changing the film thickness or column diameter. Decreases in column diameter can increase resolution but will also increase pressure and reduce sample sizes therefore reducing sensitivity. There is an old adage among chromatographers that you can want resolution, sensitivity, speed, and low cost but you cannot have them all at once. Often choosing one goal means sacrificing in another area. By understanding the function of each of the variables and how these variables can be manipulated in the chromatographic system, analysts can begin to make better choices to get the best response from their system.

Further Reading

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ABOUT THE COLUMNIST



PATRICIA ATKINS is a Senior Applications Scientist with Spex, an Antylia Scientific company and has been

a member of many cannabis advisory committees and working groups for cannabis including NACRW, AOAC and ASTM.



Cannabis Science Conference Honors the Wisdom of Women

By *Josh Crossney*

In honor of International Women's Day and Women's History Month in March, we're featuring the amazingly talented female experts that will be presenting at our upcoming 2022 Cannabis Science Conference West May 18-20 in Long Beach, California. All of these phenomenal women have played a part in the evolution of cannabis science and medicine and worked to end the stigma associated with cannabis. It is an honor to have the opportunity to work with such amazing presenters year after year. We are proud to play a part in lifting the voices of women and minorities in science, technology, engineering, and mathematics (STEM), cannabis, and psychedelics. I hope you enjoy reading about this wonderful group of individuals!

Our female speakers include (speakers listed alphabetically by last name):

- **Patricia Atkins, Senior Applications Scientist, Spex, an Antylia Scientific Company**
Talk title: Cannabis, Chemistry and Chromatography: Examining the Challenges of Cannabis Sample Processing, Analysis, and the Role of Reference Materials
- **Moriah Barnhart, Executive Director and Co-Founder, Wise FL and CannaMoms**
Panel: Pediatric Cannabis Parents
- **Laura Barrett-Nutting, MBA, BSN, RN, Clinical Director, Nurse Laura**
Panel: Expansion of the Clinical Directors Consortium
- **Gabriele Bertelli, Regional Sales Manager, Microfluidics International Corporation**
Talk title: Solubilizing Cannabis Ingredients for Improved Bio-Availability Through Nano-Emulsification Technology
- **AC Braddock, CEO, Eden Labs, LLC**
Talk title: Psychedelic Sustainability
- **Lisa Buchanan, RN, Speakers Bureau Member, Cannabis Nurses Network**
Panel: Nurses Network: A Revolution in Healthcare

- **Marcie Cooper, RN, MSN, AHN-BC, Speakers Bureau Member, Cannabis Nurses Network**
Panel: Nurses Network: A Revolution in Healthcare
Panel: A Nurses Role in Spirit Medicine: Nurturing the Psychedelic Renaissance
- **Nekeidra Cromwell, CEO, KeidyWeedy**
Talk title: Opioid Addiction Antidote
- **Heather Despres, PFC Program Coordinator, Americans for Safe Access**
Talk title: Analysis of State Cannabis Regulations
- **Dr. Alison Draisin, PsyD, LMHC, Director of KAP Provider Training, Aims Institute**
Keynote: Exploration of Protocols and Competencies in Cannabis and Psychedelic Assisted Psychotherapies
- **Tess Eidem, PhD, Director of Science, Willow Industries**
Talk title: From Microbes to Testing: Understanding and Preventing Contamination
- **Renee Engle-Goodner, MS, Principal Consultant, REG Science, LLC**
Talk title: Post-Harvest Loss Mitigation: Aspergillus Across the Supply Chain
- **Dr. Bonni Goldstein, Medical Director, Canna-Centers Wellness & Education**
Talk title: Cannabis and Children: A Pediatrician's Experience
- **Rhea Graham, Medicine Woman, Albany's Canna Kitchen & Research, LLC**
Talk title: Smokeless Cannabis Remedies
- **Kaylene Gray, NP, Clinical Director, Grow West**
Panel: Expansion of the Clinical Directors Consortium
- **Dr. Jacklyn Green, CEO, Agate Biosciences, LLC**
Talk title: Clean Cannabis
- **Sandra Guynes, MSN, RN, Speakers Bureau Member, Cannabis Nurses Network**
Panel: Nurses Network: A Revolution in Healthcare
- **Martha Hernandez, Scientist, CloudLims.com**
Talk title: How to Automate QA/QC Workflows in Cannabis Testing
Talk title: Be Lab Ready: USDA's Hemp Testing Rules Have Changed

2022 CSC West expert female presenters (not all presenters pictured).



- **Dr. Jeanette Jacknin, President, Dr. Jacknin's Skincare, LLC**

Talk title: The Minor Cannabinoids, Minor No More

- **Dr. Lakisha Jenkins-Samuels, Traditional Naturopath, Dr. Lakisha™**

Talk title: Dietary Modulation of the eCS

- **Dr. Anahid Jewett, Professor and Director of Tumor Immunology Laboratory, UCLA School of Dentistry and Medicine**

Keynote: Saving Sophie: The Mom, the Scientist, and Their Journey to Cure Cancer

- **Holly E. Johnson, PhD, Chief Science Officer, American Herbal Products Association**

Panel: The Varieties of Cannabis Regulatory Experiences: The Intersection of Standards, Regulations, and Research

- **Autumn Karcey, CEO & Founder, Alchemy 29 and Cultivo, Inc.**

Keynote: Making Sustainable Decisions in Cultivation Facility Design

- **Dr. Aimon Kopera, CEO, Geneomics Global**

Talk title: Cannabis and Beyond: The Modern Science Behind 200+ Ancient Plant-Medicine Formulations

- **Janie Maedler, President, Rylie's Sunshine and VP, Rylie's Smile Foundation**

Panel: Pediatric Cannabis Parents

- **Rylie Maedler, CEO, Rylie's Sunshine and President, Rylie's Smile Foundation**

Talk Title: A Better Path for Pediatric Patients

- **Heather Manus, RN, Founding Member, Cannabis Nurses Network**

Talk title: CA Senate Bill 311 "Ryan's Law:" California First in the Nation to Protect Rights of Medical Cannabis Patients in Hospital

Panel: Nurses Network: A Revolution in Healthcare

Panel: A Nurses Role in Spirit Medicine: Nurturing the Psychedelic Renaissance

- **Gretchen Maurer, Physician, LVHN**

Talk title: Cannabinoids for Opiate Use Disorder—Cannabis as Harm Reduction Medicine (CHaRM)

- **Scheril Murray Powell, Esq., Trade, Cannabis, Agriculture, and Dietary Supplement Attorney; Business Development Manager, Green Sustainable Strong LLC**

Keynote: International Cannabis: Trade and Supply Chain Considerations for a Global Cannabis Brand

- **Jenny Nelson, Application Scientist, Agilent**
Talk title: Official First Action AOAC Method: Metals in Cannabis
- **Dr. Heidi O'Neill, Health Scientist, Toxicologist, Cardno ChemRisk**
Talk title: Terpene Inhalation in Vaping Products: What Do We Know About Safety?
- **Nique Pichette, MSN, RN, Speakers Bureau Member, Cannabis Nurses Network**
Panel: Nurses Network: A Revolution in Healthcare
- **Jamie Rollins, BSN, RN, CYT-500, CNO, KetaMD**
Panel: A Nurses Role in Spirit Medicine: Nurturing the Psychedelic Renaissance
- **Tracy Ryan, Co-Founder/Chief Communications Officer, NKore Biotherapeutics**
Keynote: Saving Sophie; The Mom, the Scientist, and Their Journey to Cure Cancer
- **Kathleen Sanders, RPh, Pharmacist, High Winds Farm**
Talk title: Cannabis in Palliative Care
- **Stormy Simon, CEO and Co-Founder of Orle-na Home North America, Board Member, Mission Green & Kaya Holding, Former President of Overstock and Former CEO of High Times**
Talk title: My Trip into Success
- **Dawn-Marie Steenstra, LPN, SDC, Clinical Director, Entourage Consulting Services**
Panel: Expansion of the Clinical Directors Consortium
- **Kimberly Stuck, CEO, Allay Consulting, LLC**
Talk title: Cannabis Food Safety: How to Create Safe Cannabis Products and Mitigate Risk
- **Bernadette Torres**
Keynote: Sacred Tobacco the Guide for Psychedelic Plants
- **Swathi Varanasi, Chief Scientific Officer, Element Apothec**
Talk title: The Endocannabinoid System, Emotional Dysregulation, and the Gut-Brain Axis

- **Dr. Denise Vidot, Epidemiologist, University of Miami**
Talk title: Co-Use of Cannabis and Psilocybin to Manage Mental Health Amid the COVID-19 Pandemic: Preliminary Results from the International COVID-19 Cannabis Health Study
- **Becca Williams, Founder, Becca Williams International**
Talk title: The Advent of a New Paradigm: Cannabis and Psilocybin Microdosing as “Psychic Vitamins” to Release Trauma and Support Emotional Healing

Closing

I'd like to personally thank these amazing ladies for their valuable contributions to our industry and society. We hope to see more companies and events doing their part to show their appreciation of the incredible female leaders within our community in the future. Be sure to join us and these amazing presenters May 18-20, 2022 in Long Beach, California, for the world's largest and fastest growing scientific and medical cannabis event, 2022 Cannabis Science Conference West! To register and learn more, please visit www.CannabisScienceConference.com.

This article was edited for length and clarity, to read the full piece including bios for each female speaker please visit: www.cannabissciencetech.com/view/cannabis-science-conference-honors-the-wisdom-of-women/



ABOUT THE COLUMNIST

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How Poor Environmental Control Creates Pest Pressure

SAMUEL BURGNER

This article series explores some of the more technical aspects of cannabis cultivation that growers should understand to run their businesses more efficiently and more profitably. In this final article, we utilize concepts introduced throughout the series to address the pest problems created in commercial cannabis cultivation facilities when environmental control systems are improperly designed or implemented.

TOO MUCH MOISTURE in the air, on plant leaves and buds, or around the roots is the most common culprit for the development of pathogenic infection of cannabis plants. Concurrent fluctuations in temperature can be detrimental to plant vitality as infectious organisms infiltrate deeper into plant tissues during those windows of time when optimal conditions are lost. *Ascomycetes* (powdery mildew), *fusarium* (crown rot), *botrytis* (bud rot), *pythium* (root rot), and many more pathogens do not need optimal conditions to infect. They can lie dormant inside the plant (*endophytic*) or on its surface (*ectophytic*), slowly growing their way into or across the plant until the perfect moment when conditions fall outside of a safe range for the plant.

Temperature, Relative Humidity, and Pathogens

When environmental control is lost, even if only for short periods of time, diseases can quickly grow deeper into the plant's tissues. Cannabis has an optimum temperature range for highly productive growth and so do pathogens. The peak of productivity for both pathogens of cannabis and the plant itself overlap quite a bit. Typically, if the preferred temperature range for the plant is maintained, the pathogen is unable to grow at a rate that can keep up with the plant's development and so its influence is never seen, even though the infection persists. However, if for a short period of time the

temperature shifts out of the optimum range for the plant, but still lies in the optimum range for the pathogen, there will be a rapid growth response by the pathogen and symptoms may become visible as plant growth slows. This effect is often seen with fungal diseases such as *fusarium* or *botrytis* as one day the plant looks healthy and vigorous and the next it is chlorotic with water-soaked and mushy tissue.

Damage from temperature swings is not limited to direct impacts on plant tissues and stress can occur even if humidity is in a sufficient range. Only certain organisms such as powdery mildew and *botrytis* are directly dependent on the room air conditions, as opposed to water-borne diseases like *pythium* or *fusarium* which would thrive in high humidity indirectly as water movement in the rootzone is suppressed by a high-humidity induced low vapor-pressure deficit (VPD).

Excessive moisture in the air (high humidity), even if only for moments at a time, greatly encourages the growth of diseases such as powdery mildew and bud rot. It is not enough to simply monitor your room humidity sensors that control your conditioning equipment, you must identify the microclimates within your cultivation facility. If the sensor for humidity is only a panel mounted on the wall, there could be a plethora of environmental conditions happening in the room. Perhaps your humidity sensor reads right at your set-point most of the day, but if this is showing an average over a longer period of time it may not be informing you of the

Figure 1: The disease triangle. Three factors must be present for a disease to develop: the host plant, the pest or pathogen, and the environment in which both exist.



fluctuations in room air conditions. It could be that your sensor shows an average over a 10-minute period and during that time the humidity swings are $\pm 10\%$, which could enter the pathogen favoring zone quite frequently. It's not just about knowing what value is the optimum, you must ensure that you are providing those conditions uniformly and consistently.

Using HVACD Systems to Mitigate Risk

The most sophisticated (and legal) pest management products will be unable to stop the proliferation of plant pathogens if the environmental conditions cannot be kept within an acceptable range. Exposure to the pathogen is extremely difficult to avoid and even harder to maintain for extended peri-

ods of operation, especially without fully clearing material from a grow room in between each production cycle.

Although air filtration and sterilization systems can greatly reduce the threat of pathogen propagation by eliminating airborne spores or organisms, the vitality of plants must be protected and favorable conditions for those pathogens must be eliminated by ensuring excess moisture is kept at bay and that excessive temperature swings are avoided.

Heating, ventilation, air conditioning, and dehumidification (HVACD) systems have advanced quickly as the needs of the commercial cannabis industry have evolved to support a much larger market. Legacy producers have primarily maintained environmental conditions using multiple

pieces of equipment (that is, oscillating fans, standalone dehumidifiers, air conditioners, and heaters) to address individual environmental conditions. The upside to this approach is the ease of accessing retail equipment that can be added in a series to meet the changing needs of production and to provide redundancy in the case of equipment failure. The downside to this method is the variability of environmental conditions within a grow room is greatly increased as the plants are essentially located in an air mixing chamber. Pockets of high humidity form where the air is not mixed as frequently. This is most likely to happen in corners or near a source of moisture such as the grow tray, substrate, or leaves where water is evaporating continuously.

Very quickly, white fuzz can form in high humidity conditions as *ascomycetes* colonize juicy leaves. Think of a newly sprouted seed—if it emerges and then conditions become dry, it is likely to die. If humid conditions remain, the roots have more time to establish a water column in the vascular tissue as the leaves acclimate to the air conditions. If it stays too wet, the root will likely rot as it is suffocated by oxygen-deficient water, leaving an opening for a pathogen to attack. You may have noticed some seedlings turn to white or gray mush when left in a tray that is too wet.

Some producers will keep humidity levels very low to avoid any chance of pathogens growing, but leaves need a certain amount of moisture in the air as well to remain healthy and this will change depending on the air temperature, light source, and maturity of the plant. If conditions are too dry while the lights are on, photosynthesis can be inhibited for several reasons. If they are too dry while the lights are off, xylem-based nutrient movement into the newly developing tissues can be inhibited, specifically calcium movement into the new growth is inhibited. Cell wall development requires a constant supply of calcium to form rigid structures that effectively prevent intrusion by pathogens. Calcium primarily enters plants through meristematic tissues (the foremost tip of a root or shoot) as the cell wall is still forming

at this location exposing the vascular tissue where calcium can enter the plant and be transported into developing tissues through the unidirectional water stream called the xylem. If VPD is very high, calcium is likely to be shuttled into the tissues where transpiration is the highest, which is likely to be the large mature leaves with the most developed stomata. This shuttling of calcium away from newly developing tissues encourages poor cell wall development, leaving plants weak and susceptible to attack.

Final Thoughts

Ultimately, plant vitality will be strongest when plants are able to thrive without constantly adapting to shifting conditions. In nature, a plant must deal with an array of stressful circumstances, and it is loaded with mechanisms to ward off threats and protect itself from a shifting environment. However, these adaptations cost metabolic energy and will reduce plant productivity, yield, and end-product quality.

Many of these points are often overlooked as producers seek out short-term solutions to chronic issues caused by poor HVAC design and, subsequently, environmental control. Rather than pursue topical products to suppress pest issues, investigate what aspects of your environmental control systems might be providing an optimum habitat for pests to thrive rather than plants. Identify the microclimates

and make attempts to de-stratify these pockets and you will see great improvements in the overall health of your facility.

Further Reading

- (1) R. Batts and S. Burgner, *Cannabis Science and Technology* 4(2), 32-34, 38 (2021). <https://www.cannabissciencetech.com/view/why-does-leaf-temperature-matter-in-a-commercial-grow-room>.
- (2) R. Batts and S. Burgner, *Cannabis Science and Technology* 4(4), 29-32 (2021). <https://www.cannabissciencetech.com/view/a-deep-dive-into-vapor-pressure-deficit-for-commercial-cannabis-cultivation>.
- (3) R. Batts and S. Burgner, *Cannabis Science and Technology* 4(7), 38-42 (2021). <https://www.cannabissciencetech.com/view/does-light-spectrum-alter-plant-transpiration-rates>.
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about the author

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Why All Legalized US Jurisdictions Should (and Probably Will) Adopt the International Intoxicating Cannabis Product Symbol (IICPS)

DAVID L. NATHAN AND ELI NATHAN

AS INDIVIDUAL US states and the federal government approach legalization of cannabis for medical and adult use, a universal symbol for cannabis products is essential to the protection of public health and safety.

Currently, states that have legalized cannabis for medical or adult use have implemented differing requirements for cannabis labeling. These standards vary widely, and in the absence of federal standardization, the solutions that are best for one jurisdiction may not be suitable for another.

Nonetheless, there is one anchor point to ensure that Americans of all ages and backgrounds can correctly identify and exercise caution with cannabis products: a universal symbol on cannabis packages. Such a symbol is critical for, among other reasons, preventing the accidental ingestion of cannabis by adults and children.

However, no cannabis product symbol has met with approval by more than one or two legalized US states, which is a serious issue of public safety now facing regulators, medical professionals, industry stakeholders, patients, consumers, and the general public.

Working with Doctors for Cannabis Regulation and other stakeholders, David L. Nathan, MD, proposed the Universal Cannabis Product Symbol (UCPS) in 2019. After its publication in 2020 (14), a broad discussion with various stakeholders led to a series of changes to the UCPS. Working with the standards organization ASTM, the authors of this paper co-designed a modified version of the UCPS (8), which was renamed the International Intoxicating Cannabis Product Symbol (IICPS) (Figure 1).

At the time of the publication of this article, the IICPS had already been included in the proposed rules for the state of Montana (15), and other newly legalized states are

planning to follow suit. Also at the time of this publication, ASTM was actively engaged in an approval process that would make the IICPS the one and only cannabis product symbol to be designated as an internationally recognized consensus standard.

What's In a Name?

The word "Intoxicating" was added to the name of the symbol to distinguish hemp products from intoxicating cannabis products. The *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition (DSM-5) defines Cannabis Intoxication as meeting all of four criteria (1):

- A. Recent use of cannabis.
- B. Clinically significant problematic behavioral or psychological changes (for example, impaired motor coordination, euphoria, anxiety, sensation of slowed time, impaired judgment, social withdrawal) that developed during, or shortly after, cannabis use.
- C. Two (or more) of the following signs or symptoms developing within 2 hours of cannabis use:
 1. Conjunctival injection
 2. Increased appetite
 3. Dry mouth
 4. Tachycardia
- D. The signs or symptoms are not attributable to another medical condition and are not better explained by another mental disorder, including intoxication with another substance.

In 2021, tetrahydrocannabinol (THC) was the main intoxicating compound in all known varieties of the cannabis plant. Thus, any cannabis products surpassing a defined threshold of THC content should bear the IICPS. Definition

Figure 1: The International Intoxicating Cannabis Product Symbol (IICPS) symbol.



Figure 2: Currently used cannabis product symbols compared to the IICPS.



of this critical threshold of THC content (typically expressed as a weight in milligrams or as a percentage by weight of the product) is a controversial topic beyond the scope of this paper.

Currently Used Cannabis Product Symbols

Ten US states and the nation of Canada have adopted nine different intoxicating cannabis product symbols. All of them have design problems, generally pertaining to color, shape, symbology, or the prohibited use of text inside a graphical symbol (see **Figure 2** and **Table I**). The International Intoxicating Cannabis Product symbol (IICPS) is an alternative to the many symbols currently in use, but with a fundamental difference: It is firmly rooted in accepted principles of symbology and consensus standards.

Consensus Standards

A truly universal symbol must adhere to existing standards of packaging, labeling, and design. And, in order to be accepted by the US federal government, the symbol should be a consensus standard.

Consensus standards are technical specifications issued by standards development organizations (also called voluntary

consensus bodies) such as the American National Standards Institute (ANSI), ASTM, and the International Organization for Standardization (ISO) (2–6,10–13). They are developed in an open environment through collaboration by professionals from both the public and private sectors. This is achieved by cooperation of all parties who have an interest in participating in the creation or use of the standards. Consensus standards incentivize universal compliance beyond recommendations, guidelines, or best practices developed by single individuals, organizations, or particular authorities having jurisdiction (AHJs).

Further, the use of consensus standards is mandated by federal law. The National Technology Transfer and Advancement Act of 1995 (NTTAA) requires the federal government to use privately developed consensus standards whenever possible. The NTTAA codifies what was long considered to be best practice within the federal government.

The NTTAA, Section 1115 of Public Law 107-107, Section 12(d) states (7):

- (d) UTILIZATION OF CONSENSUS TECHNICAL STANDARDS BY FEDERAL AGENCIES; REPORTS.—
- (1) IN GENERAL.—Except as provided in paragraph (3) of this subsection, all Federal agencies and departments shall use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments.
- (2) CONSULTATION; PARTICIPATION.—In carrying out paragraph (1) of this subsection, Federal agencies and departments shall consult with voluntary, private sector, consensus standards bodies and shall, when such participation is in the public interest and is compatible with agency and departmental missions, authorities, priorities, and budget resources, participate with such bodies in the development of technical standards.
- (3) EXCEPTION.—If compliance with paragraph (1) of this subsection is inconsistent with applicable law or otherwise impractical, a Federal agency or department may elect to use technical standards that are not developed or adopted by voluntary consensus standards bodies if the head of each such agency or department transmits to the Office of Management and Budget an explanation of the reasons for using such standards. Each year, beginning with fiscal year 1997, the Office of Management and Budget shall transmit to Congress and its committees a report summarizing all explanations received in the preceding year under this paragraph.

Table I: Attributes of all symbols in Figure 2. Note that green denotes desirable attributes, while red denotes undesirable attributes, according to existing consensus standards. Consensus standards, as described in the text, dictate that the shape of a safety sign urging caution should be a warning triangle. The ideal number of colors in a graphical symbol is two (and white is considered a color in this context), as more colors unnecessarily increase the cost of packaging. The symbol should have a black and white option for jurisdictions that do not require color printing. This requires that non-white elements of the symbol are separated, or that the symbol uses only two colors. The emphasized color of a symbol should be consistent with existing conventions, in which red implies prohibition, yellow implies warning, and green implies a safe condition (see Table II). Standard safety signs should contain only graphical elements within their borders, not text or punctuation. Only large design elements should be included. Finally, safety signs should be fully compliant with ISO and ANSI consensus standards, as described.

	Shape (Conventional meaning)	Number of colors (including white)	Black & white option (two colors, or non- white elements separated)	Conventional meaning of emphasized color	Graphical element (cannabis leaf)	Text or punctuation within symbol	Large design elements	ISO & ANSI compliant
AR	Rectangle (none)	2	✓	None		✓	✓	
CA	Triangle (warning)	2	✓	None	✓	✓		
CO	Diamond (none)	2	✓	Prohibition red		✓		
MA & ME	Triangle (warning)	3	✓	Prohibition red	✓		✓	
MI	Inverted triangle (none)	2	✓	Safe condition green	✓	✓		
NV	Triangle (warning)	2	✓	None		✓		
OK	Rectangle (none)	3	✓	Prohibition red	✓	✓	✓	
OR	Rectangle (none)	3		Prohibition red	✓	✓	✓	
WA	Diamond (none)	4		Warning yellow & safe condition green	✓	✓		
Canada	Octagon (stop)	3		Prohibition red	✓	✓		
IICPS	Triangle (warning)	2	✓	Warning yellow	✓		✓	✓

- (4) DEFINITION OF TECHNICAL STANDARDS.—As used in this subsection, the term “technical standards” means performance-based or design-specific technical specifications and related management systems practices.

Multiple standards development organizations have approved safety signs and caution symbols that are accepted standards in the US and around the world, and those consensus standards may be readily applied to a universal cannabis product symbol.

Safety Signs

The international consensus standard for safety symbols is ISO 3864 (10–12), which corresponds to the similar US consensus standard ANSI Z535.4: *Product Safety Signs and Labels* (3).

ISO 3864 standardizes five safety signs as shown in **Table II**.

For a cannabis product symbol to be compliant with consensus standards, then one of these safety signs must be chosen. Thus, a symbol indicating prohibition, mandatory action, safe condition, or fire equipment would be inappropriate. The only logical option is the standard warning

Table II: Data from Table II in ISO 3864-1: Graphical symbols—Safety colours and safety signs—Part 1: Design principles for safety signs and safety markings (10).

Geometric shape	Meaning	Safety colour	Contrast colour to the safety colour	Graphical symbol colour	Examples of use
 Circle with diagonal bar	Prohibition	Red	White ^a	Black	— No smoking — Not drinking water — Do not touch
 Circle	Mandatory action	Blue	White ^a	White ^a	— Wear eye protection — Wear protective clothing — Wash your hands
 Equilateral triangle with radiused outer corners	Warning	Yellow	Black	Black	— Warning; Hot surface — Warning; Biological hazard — Warning; Electricity
 Square	Safe condition	Green	White ^a	White ^a	— First aid — Emergency exit — Evacuation assembly point
 Square	Fire equipment	Red	White ^a	White ^a	— Fire alarm call point — Collection of fire fighting equipment — Fire extinguisher

^a The colour white includes the colour for phosphorescent material under daylight conditions with properties as defined in ISO 3864-4.

Figure 3: The cannabis leaf in the IICPS.



Figure 4: The IICPS on light and dark backgrounds. Note the additional yellow border against the dark background.



sign, which consists of a black graphical symbol inside a black-bordered yellow equilateral triangle with radiused outer corners.

Letters, numbers, punctuation marks, and mathematical symbols may not be included in standard graphical symbols, with the sole exception of an exclamation point as the graphical symbol in two signs: the General Mandatory Action Sign (ISO 7010-M001) and the General Warning Sign (ISO 7010-W001) (13). Not one of the hundreds of other registered safety signs in ISO 7010 includes an exclamation point or any other letter, number, or punctuation mark. This strict standard ensures comprehensibility of graphical safety signs by anyone, regardless of age, literacy, and language differences.

People may not recognize “THC” as identifying a cannabis product if they are young, illiterate, do not use the Latin alphabet, or lack specific education about cannabis. Thus, the use of “THC” inside a cannabis product symbol is not just prohibited by consensus standards—it’s also discriminatory.

Creation of the International Intoxicating Cannabis Product Symbol

The International Intoxicating Cannabis Product Symbol (IICPS), intended to symbolize “caution with cannabis,” was

the product of a collaboration between cannabis policy experts and designers, utilizing existing standards. This effort is part of a larger project for standardized cannabis labeling initiated by Doctors for Cannabis Regulation (9).

When setting out to design the IICPS, the creators stipulated that it must satisfy a strict set of criteria:

- Adhere to existing precedents of standard symbols, so the public will immediately understand the meaning of the symbol.
- Use symbology that transcends age, literacy, knowledge of the Latin alphabet, specialized knowledge about cannabis, language, and culture.
- Allow for the addition of optional text to meet the needs of authorities having jurisdiction in the US and around the world.

This is not a stop-gap solution until some other design is developed. This is the solution—a symbol designed for permanent use by individual states, the federal government, and other nations.

IICPS Symbology

ISO 3864-2 (11) requires that the standard warning sign include a black graphical symbol within the yellow triangle. ISO 3864-3 (12) specifies that the graphical symbol inside a warning symbol should:

- Utilize objects, concepts, and activities, or a combination of these, which are familiar to the target group
- Contain only those details that contribute to understanding
- Be readily associated with its intended meaning
- Be easily distinguishable from other graphical symbols

For cannabis products, the only symbol that satisfies these criteria is a cannabis leaf. It is far and away the most familiar graphical symbol associated with cannabis. A joint, bong, or other paraphernalia, for example, would limit the scope of the symbol and require the consumer to make a logical jump from cannabis to paraphernalia that may be unfamiliar to many. An

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Figure 5: Measurements demonstrating the compliance of the IICPS with standards set forth by ISO 3864. The thin red triangle around the cannabis leaf in the first image shows the exclusion zone within which the central cannabis leaf must be contained.

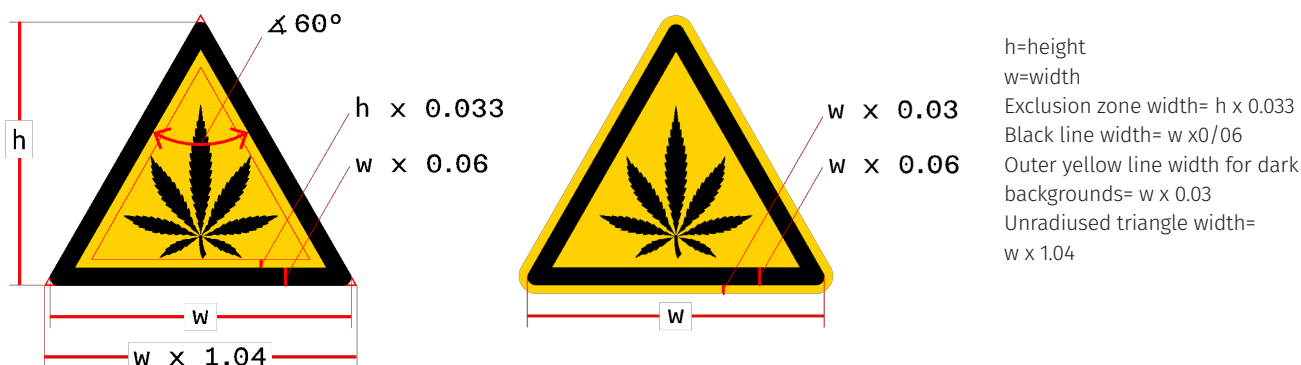


Figure 6: ISO compliant versions of the IICPS with text below the symbol.



The IICPS creators thus concluded that the cannabis leaf is the only suitable symbol to be placed within the warning triangle (Figure 3).

The size and shape of the leaf were carefully chosen to include several desirable characteristics:

- The leaf has a distinct shape and serrated margins to distinguish it from the leaves of other plant species, thus reinforcing the public's accurate identification of cannabis plants.
- The leaf has well-separated leaflets that remain clear at small sizes, as when printed on vape cartridges or embossed on edible servings.
- The leaflets have a silhouette and leaflet count that is intermediate between those of typical mature leaves of the two main varieties of the cannabis plant (*Cannabis sativa* L.): "indica" and "sativa."

Putting together the standard warning sign and the cannabis leaf, the International Intoxicating Cannabis Product Symbol was born (Figure 4). The design of the IICPS is fully compliant with ISO 3864 and ANSI Z535 (Figure 5).

Supplemental Text Options

Consistent with ISO 3864, the IICPS is designed to permit the use of text below the symbol, so alphanumeric or special characters may be placed under the symbol for supplemental information (Figure 6). This allows for uniformity in the symbol while meeting the varying needs of authorities having jurisdiction in the US and around the world. It also obviates any purported need for the inclusion of letters, numbers, or special characters inside the symbol itself.

exclamation point cannot be included in the design, as alphanumeric characters and punctuation marks are forbidden in all consensus standard symbols, except for the generic warning sign with an exclamation point. Also, an exclamation point does not add to recognition of the symbol and would require that the cannabis leaf inside a warning triangle be reduced to an undesirably small size (see California's cannabis product symbol in Figure 2).

Black and White Option

A black and white version of the IICPS falls outside ISO and ANSI standards for warning signs, which mandate the use of “warning sign yellow” (Pantone 109) as a background color. Thus, it should be used only if color printing is impossible and black and white printing of the IICPS is permitted by the authority having jurisdiction (**Figure 7**).

Ready for Use Now

We present the IICPS to regulators with a simple message: This is not just the right choice as a universal symbol for cannabis products—it’s also the safe choice.

The IICPS is the only cannabis product symbol in the world that is on track to become a consensus standard (6). It is undergoing approval through the international standards development organization ASTM. The IICPS was unanimously approved by the working group developing a symbol for ASTM’s Committee D37 on Cannabis. The final step is the pending approval of ASTM WK75247—Specification for an International Symbol for Identifying Consumer Products Containing Intoxicating Cannabinoids by the full committee membership of more than 1000 stakeholders.

Typically, once one major standards development organization publishes a consensus standard, the others will support it unless there is a compelling reason to reject it. Regardless, the designers of the IICPS believe that if another standards development organization set out to create a universal symbol for cannabis products, existing precedents for warning signs and the ubiquity of the cannabis leaf as a representative graphical symbol would guide another organization to choose a design that is fundamentally indistinguishable from the IICPS.

When this symbol becomes the ASTM consensus standard, and cannabis is regulated at the national level, US federal regulators will likely be obligated to use the IICPS under the National Technology Transfer and Advancement Act of 1995 (NTTAA).

Organizational Support for the IICPS

The authors invite cannabis stakeholders to support the IICPS by formally endorsing its use by states, the federal government, and other authorities having jurisdiction. Please contact labeling@dfcr.org to discuss adding your organization’s name to the list of endorsing organizations.

Next Steps for Regulators

To facilitate immediate adoption by regulators, the designers have published the symbol in multiple digital file formats (for example, PDF, EPS, SVG, and JPG) for distribution and use.

Figure 7: The IICPS in black and white.



The symbol will be available for use by regulators worldwide: on demand, in perpetuity, royalty-free, and at no cost.

Regulators may address any questions or requests for IICPS digital files to labeling@dfcr.org.

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Capacity: 2102g
Scale Interval: 0.01g

CUSTOMER
Customer: [blank] Capacity: 2102g
Verification Interval: 0.1g

METHOD
Calibration Procedure: PV01 rev. 01 of 4/20/2018

ENVIRONMENTAL
At temperature: (20 ± 0.5) °C
Relative humidity: (50 ± 1.2) %

DATE PERFORMED: 0/0/00 0/0/00

TRACEABILITY			
Model	Serial	Cal. Date	Cal. By
SPS-2102T.N	12345678	10/1/2021	D-4-1510-01-00
SPS-2102T.N	12345679	10/1/2021	D-4-1510-01-00
SPS-2102T.N	12345680	10/1/2021	D-4-1510-01-00
SPS-2102T.N	12345681	10/1/2021	D-4-1510-01-00

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