

# Microcrystalline Tests in Forensic Drug Analysis

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<b>1 Introduction</b>	<b>1</b>
1.1 History	2
1.2 Modern Use	2
<b>2 Chemical and Forensic Context</b>	<b>2</b>
2.1 Microchemical Identification	2
2.2 The Value of Microcrystalline Tests for Forensic Drug Analysis	2
2.3 Type of Evidence Provided by Microcrystalline Tests	3
<b>3 Technical Aspect</b>	<b>4</b>
3.1 General Principle of Microcrystalline Tests	4
3.2 Sample and Reagent Preparation	4
3.3 Crystal Growth	5
3.4 Crystal Classification and Description	6
3.5 Storage, Shelf Life, and Sample Recovery	8
<b>4 Application Examples</b>	<b>8</b>
4.1 Cocaine	8
4.2 Diamorphine (Heroin)	9
4.3 Methadone	9
4.4 $\gamma$ -Hydroxybutyrate	9
4.5 Ketamine	10
4.6 Phencyclidine	10
4.7 Amphetamines and Methamphetamine	10
<b>Acknowledgments</b>	<b>12</b>
<b>Abbreviations and Acronyms</b>	<b>12</b>
<b>Related Articles</b>	<b>12</b>
<b>References</b>	<b>12</b>

*Drug detection in the forensic context requires numerous analytical techniques. Depending on locally adopted standard procedures, different techniques are used for screening solid samples for potential illicit substances (e.g. Fourier transform infrared spectroscopy (FTIR)). A sample suspected of containing prohibited material passes through another layer of techniques to confirm that the illegal substance is present and to identify it (e.g. liquid/gas*

*chromatography). Finally, the drug is systematically quantified (e.g. mass spectrometry). Microcrystalline tests fall within the second step of this analytical process. They are low cost because of the minute amount of reagents used and the simplicity of the instrumentation and consumables required to perform the analysis. They offer all the features required by a good confirmation technique while being very fast to administer and interpret, although they do not offer quantification capabilities.*

*Microcrystalline tests are chemical tests resulting in the formation of unique microcrystals for a given substance when combined with a specific reagent. Microcrystals are observed under a microscope and micrographs or microvideos constitute the results of the test.*

*Thanks to the chemical mechanism by which microcrystals develop, microcrystalline tests can be applied to molecules of various sizes, shapes, charges, and with different functional groups, and can naturally distinguish between enantiomers.*

## 1 INTRODUCTION

Forensic drug analysis is a vast field that involves the application of a range of analytical techniques to identify and quantify drugs of abuse, to support authorities during investigation proceedings. Abuse of drugs is a worldwide health problem touching all layers of the population irrespective of age and socioeconomic background.

In 1961, an international treaty was signed: the Single Convention on Narcotic Drugs (SCND), which prohibits the production and supply of specific drugs (or related drugs) except those under license for medical or research purposes. The substances addressed by the SCND were opiates, cocaine, and cannabis. In 1971, the Convention on Psychotropic Substances (CPS) added lysergic acid diethylamide (LSD), Ecstasy, and other psychotropic drugs. Finally, the United Nations Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances introduced regulations on precursors in 1988.

The SCND offered a base to develop national regulations across the globe, for example, the Substance Control Act in the United States (1970) and the Misuse of Drugs Act in the United Kingdom (1971).

Commonly abused substances regulated in these acts include opioids (morphine, heroin, codeine, and methadone), cocaine, amphetamine, methamphetamine, 3,4-methylenedioxymethamphetamine (MDMA), cannabis, benzodiazepines,  $\gamma$ -hydroxybutyrate (GHB), flunitrazepam, phencyclidine (PCP), and barbiturates.

Numerous analytical techniques exist to screen seized material for the presence of drugs and to quantify any amount detected. In this analytical framework, the

purpose of microcrystalline tests is to make a definite and final identification when a drug is present in a sample.

### 1.1 History

In the early 1800's chemists started to apply reagents on drugs, pharmaceuticals and food stuffs and observed reactions such as color changes through a microscope. With the development of the polarized light microscope, the observation of crystals evolved rapidly because it reveals local differences in specimen structures, although it was mostly utilized for mineralogy.<sup>(1,2)</sup>

In 1827, Raspail introduced the term "chemical microscopy".<sup>(3)</sup> By then he had already discovered microchemical tests for the detection of sugars, oils, and albumin within cell material. In the middle of the nineteenth century, toxicologists started to study crystal formations of alkaloids when combined with reagents, and the first crystal tests emerged. From then on, microcrystalline tests developed more systematically up to the publication of "Microchemistry of Poisons" by Wormley in 1867, which included microcrystal illustrations engraved upon steel.<sup>(4)</sup>

The technique evolved across inorganic and organic chemistry from the simple use of a microscope to aid chemical identification to the development of reactions that led to the formation of characteristic crystals.

Fulton published the only textbook on microcrystalline tests, which covers numerous microcrystalline tests for the identification of narcotics and drugs of abuse from simple test setup to result in the interpretation and development of new tests.<sup>(5)</sup> This provided a detailed classification for crystal characterization including numerous microphotographs showing various shapes and appearances.

Clarke extended the range of microcrystalline tests mostly focusing on toxicology applications.<sup>(6)</sup> At a time when analytical techniques such as chromatography were evolving fast but could not yet routinely be used to identify unknown drugs, reliable microchemical tests such as microcrystalline and color tests were needed and developed.

After 1969, publications on microcrystalline tests for drugs were based either on Fulton's or on Clarke's work and only rarely contained new tests.

However, when modern separation and detection techniques, especially gas chromatography/mass spectrometry (GC/MS) and liquid chromatography/mass spectrometry (LC/MS) became widely available and reliable, techniques that did not provide any molecular, structural, and/or compositional information were gradually neglected and eventually used as presumptive/screening tests. Microcrystalline tests were entirely removed from Clarke's *Isolation and Identification of Drugs*, second edition (1986).<sup>(7)</sup>

### 1.2 Modern Use

It is difficult to assess how widely microcrystalline tests are now used for forensic drug analysis. On the basis of the small number of recent publications, research activity in the development of microcrystalline tests seems limited, and existing guides issued by the American Society for Testing and Materials (ASTM) describing such tests are outdated.

However, the recent emergence of GHB on the drug facilitated sexual assault (DFSA) scene has seen the sudden publication of three papers proposing microcrystalline tests for this drug.<sup>(8-10)</sup>

Indeed, GHB being a very small ( $104.1 \text{ g mol}^{-1}$ ) and simple molecule, finding a specific test for it was challenging. Nevertheless, GHB can be detected effortlessly using a microcrystalline test, thanks to the technique mechanism.

## 2 CHEMICAL AND FORENSIC CONTEXT

### 2.1 Microchemical Identification

A microcrystalline test is a chemical test and the result is a microcrystal observed under a microscope. After allowing the sample to meet with a carefully chosen reagent, testing whether a drug is present using this technique relies on comparing the shape, size, color, and spatial arrangement (also called *habit*)<sup>(6)</sup> of the microcrystals formed with the those formed in a control with the same reagent. The control is an authentic sample of the drug tested for. If the crystal's shape, size, color, and spatial arrangements match, the analyst can conclude a positive identification of the drug.

### 2.2 The Value of Microcrystalline Tests for Forensic Drug Analysis

The microcrystalline test technique is often wrongly classified as a screening technique and/or a presumptive technique. A microcrystalline test should be classified and considered as a confirmation technique with screening capability.

A good confirmation technique must have three main qualities. First, the technique needs to present a certain predictive aspect where the results obtained are expected. The confirmation technique is chosen because of its specificity and sensitivity for the suspected substance. Second, the technique should consider the whole compound and not just its reactive groups. Finally, a confirmation technique must be different, either in its nature or its results, from any test previously used to screen and identify the substance. Different analytical techniques base substance identification on

different principles: e.g. retention times/Kovacs indices in liquid or gas chromatography, fragmentation patterns in mass spectrometry, and transmitted energy at specific wavelengths in FTIR spectroscopy. Similarly, the type of data generated ranges from the intensity discharged at a particular emission wavelength, measured with a fluorescence detector, to the relative abundances of fragment species in a mass spectrum, depending on the detection technique employed. A good confirmation technique is carefully chosen considering the identification technique employed, because it needs to add a new layer of evidence to the entire analytical process.

GC/MS is the main confirmation technique employed for forensic drug analysis because it fulfills all criteria of a good confirmation technique by combining two different identification techniques (GC and MS), and presents the advantage of coupling confirmation and quantification when necessary. However, before injecting into a GC/MS, it is often required to derivatize substances to reduce the polarity and enhance the volatility of high molecular weight polar drugs, to stabilize a thermally unstable drug (e.g. GHB dehydrates to GBL in the injector's liners),<sup>(11)</sup> or to increase the molecular weight of very volatile drugs to complex the fragmentation profile, thus increasing the confidence in identification/confirmation. In such cases, the substance is not directly analyzed: the derivative of the drug is considered. Therefore, while considering the whole molecule, the GC/MS technique is often indirect when the derivatization of the compound is required before analysis.

Microcrystalline tests are direct tests: the tested substance is directly the cause for an observable effect. These tests also fulfill all the criteria of a good confirmation technique. First, the test reagent is specifically chosen to induce the development of specific microcrystals with the analyte and the test is invariably compared with a control test. This demonstrates the predictive manner in which microcrystalline tests are used. Secondly, the tested drug molecule is an integral part of the microcrystal formed (Section 3.3) unlike other tests in which the analyte simply induces a change in the reagent (like most color tests). The shape and growth directions of the crystals are dictated by the physical and chemical properties of the molecule. Finally, the microcrystalline testing technique principle and the type of results produced (micrograph/microvideo) are unique compared to any other analytical technique in forensic drug analysis, therefore adding new evidence to the analytical case.

Moreover, to be carried out microcrystalline tests do not require the highest purity of substance. Some purification procedures can sometimes be used before testing (Section 3.2). However, provided that other substances do not react in a similar way, if at all, with the reagent

used to carry out the test, and provided that the impurities, diluents, and adulterants reactions of the with the reagent do not prevent or mask the formation of characteristic microcrystals for the drug tested, the sample can be analyzed directly without predetection separation of the target compound from its matrix.

An analyst could be tempted to try to relate the amount or the size of the microcrystal formed with the abundance of the tested drug in the sample. However, the number of crystals formed and their sizes can greatly vary with the temperature, hygrometry, and pressure under which the experiment takes place as well as with the presence of diluents/adulterants. No published attempt to quantify a substance has been reported using the microcrystalline testing technique.

Finally, microcrystalline tests need to be specific as opposed to indicative or characteristic. Sometimes, a reagent induces resemblance between the microcrystals formed with two or just a small number of drugs while being very different from any other substances. In cases where differences between the two microcrystals formed are too minute, the microcrystalline test is considered highly characteristic for the singled out compounds but not specific enough to be used as a confirmatory test. However, this nonspecific but highly characteristic reagent can be employed as a powerful screening test.

In absolute terms, a test can only be called specific after having tested every single existing substance with a reagent and witnessing that the specific microcrystals obtained occur only for one particular targeted compound. However, because of the predictive context in which microcrystalline tests are utilized, this is not an issue.

### 2.3 Type of Evidence Provided by Microcrystalline Tests

Recording the results of a microcrystalline test is very straightforward. In addition recording the shape, size, color, spatial arrangement of the microcrystals formed, and the magnification used in writing, the analyst takes a micrograph of both sample and control. The microphotographs must show a scale for comparison purpose between sample and control. The scale used has to be introduced using a graticule slide. Nowadays, digital microscope software (such as GE5 Digital Microscope R1.0.0.1 from View Solutions, Inc.) are capable of converting pixels into micrometers instantaneously, taking into account the magnification used. They also allow very precise direct measurements of the crystals dimensions, angles, areas, and cluster radius, instead of just showing a scale of the micrograph.

Moreover, the digital microscope is capable of recording videos of a microcrystalline test. This is a

considerable advantage over a classic microscope because it addresses various problems intrinsic to the technique when it comes to microcrystal observation. First, several microcrystalline tests see the formation of reagent crystals (crystals formed by the reagent on its own) on top of the crystals of interest, sometimes leading to difficulties in spotting them. Fortunately, reagent crystals and drug crystals do not form at the same time: the reagent crystals generally appear later. Without the capacity to film the test, the analyst has to keep monitoring the development of the microcrystals because there is no definite time when the crystal of interest will have grown enough to be interpreted. The development time is dependent on temperature, hygrometry, and analyte concentration. Moreover, reagent crystals can form very suddenly and rapidly all over the monitored area; sometimes, even while the analyst is trying to take the microphotograph. Secondly, some microcrystalline tests see the development of transient microcrystals of variable lifetime, which may be missed by the observer. This is particularly true for very low concentrations of the drug. Possessing a full record of the test allows the analyst to go back in time on suspicion that transient crystals may have occurred.

Therefore, the analysts can record the full length of the test and study the video afterward and easily snapshot the test at any point in time.

Micrographs and microvideos constitute permanent records that are very straightforward to present in court. Microcrystals are specific and a simple rapid comparison between the sample and the control will undeniably prove the drug present if the test is positive.

### 3 TECHNICAL ASPECT

#### 3.1 General Principle of Microcrystalline Tests

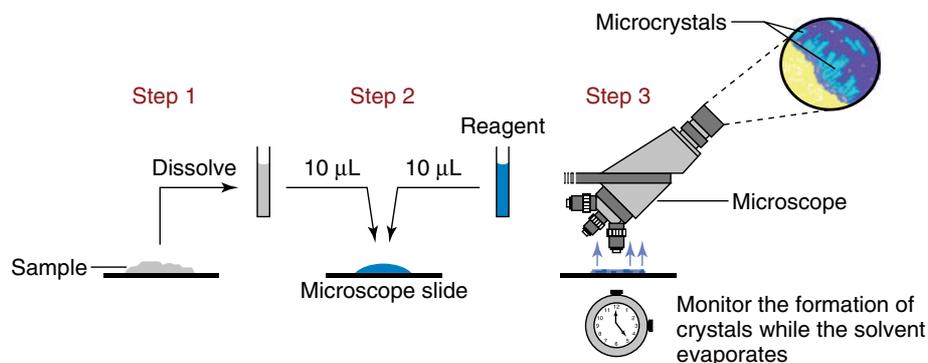
Performing a microcrystalline test is straightforward and is described in Figure 1.

Step 1 is discussed in detail in Section 3.2. Step 2 consists of applying a microdrop of the sample in the solution on a glass slide and depositing a microdrop of the reagent solution on top of it. Microdrops volume usually ranges from 1 to 50  $\mu\text{L}$  depending on the available sample size and should not be generalized. Typically, the reagent microdrop will have the same volume as the sample. Using a plastic pipette tip, some gentle stirring of the combined liquid droplets can be applied to encourage the reagent to diffuse in the sample when their respective solvents are of very different viscosity (e.g. when glycerol is used in the reagent solution). The stirring should not exceed a few seconds because this will result in the distortion of the crystals that are forming. Alternatively, it is possible to mix the sample and the reagent solutions before applying a microdrop of the mixture on the slide. However, this should not make any significant difference because of the low concentrations generally utilized in microcrystalline tests. In Step 3, the analyst constantly monitors the test looking for the formation of microcrystals specific to the substance tested for. Alternatively, a digital microscope can be set to record the length of the test (Section 2.3).

Chemically, microcrystalline tests are simple addition reactions where the targeted drug complexes with a reagent; the addition products formed crystallize as their concentration increases. The chosen solvent should favor the reaction by ensuring optimum solubility of the drug and the reagent. Typically, the reagents are heavy metals complexed with halogens, but any complex acids and anions are potential reagents when testing for new substances (Table 1).

#### 3.2 Sample and Reagent Preparation

Before the test, solid samples may need to undergo some purification procedure. It is always advisable to observe powders under a microscope to evaluate their homogeneity. If they are found heterogeneous, a mechanical separation of the different grains is performed under a microscope when possible.



**Figure 1** General microcrystalline test principle.

**Table 1** Examples of reagents

Complex metal halides	Organic acids	Simple oxygen acids
HAuCl <sub>4</sub>	Picric acid	Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup>
HAuBr <sub>4</sub>	Picolonic acid	MnO <sub>4</sub> <sup>-</sup>
H <sub>2</sub> PtCl <sub>6</sub>	Trinitrobenzoic acid	ClO <sub>4</sub> <sup>-</sup>
H <sub>2</sub> PdCl <sub>4</sub>	5-nitrobarbituric acid (dilituric acid)	
Basic reagents	Complex oxygen acids	Neutral or basic reagents
Na <sub>2</sub> CO <sub>3</sub>	Phosphorimolybdic acid	Iodine-KI
Na <sub>3</sub> PO <sub>4</sub>	Arsentimolybdic acid	HgCl <sub>2</sub>
NH <sub>4</sub> OH		NH <sub>4</sub> Cr(NH <sub>3</sub> ) <sub>2</sub> (SCN) <sub>4</sub> (Reinecke salt)

Most good microcrystalline tests do not require further preparation; however, in cases where the diluents or adulterants interfere strongly with the formation of the expected characteristic microcrystals obtained for the target compound, the analyst may choose to use thin layer chromatography (TLC), liquid–liquid extraction (LLE), or solid phase extraction (SPE) to purify the sample before microcrystalline testing it.

In the case of liquid samples (e.g. freebase cocaine in diethyl ether, GHB syrup), the samples are evaporated to dryness at room temperature under a stream of inert gas before testing, although applying heat could induce loss of material and/or denature the sample. This has the added advantage to facilitate the preparation of an adequate concentration of the sample in an adequate solvent for the test.

Most microcrystalline tests require the drug to be initially put into aqueous solution. The solvent of choice was water for a long time until Fulton started to modify aqueous tests with HCl, then extended the range to phosphoric, acetic, and sulfuric acids of various concentrations.<sup>(5)</sup> Indeed, if acid drugs readily unite with cations in water, an acidic environment helps basic drugs and amphoteric substances to connect with the reagents.

Up to 50% ethanol is sometimes incorporated in some tests to help dissolving certain substances; however, a higher proportion is to be avoided because it tends to precipitate reagents. Glycerol is often used as an additive to the reagent because it slows down the crystallization process and allows more time for the ion–drug complexes to pack harmoniously.<sup>(5)</sup> It also often lengthens the time necessary for reagent crystals to appear, which is desirable. It is unwise to try to slow down the evaporation rate using a cover slip because crystals are three-dimensional entities and would end up being distorted and uncharacteristic.

Typically, reagents range between 0.1% and 2% in concentration.<sup>(5,6)</sup> Few tests necessitate a higher concentration and numerous tests show more crystal formation with far less reagent. A forensic analyst always tries to minimize the concentration of the

reagent used because it lowers the formation of reagent crystal, potentially interfering with the observation of the microcrystals of interest. It also has the benefit of lowering the cost of the tests.

Ideally, the drug concentration should be approximately the same as that of the reagent. This is often difficult to achieve because of the unknown quantity of diluents, impurities, and adulterants present in the sample; however, an experienced analyst knows what kind of levels are to be approximately expected and invariably prepares a series of dilutions of the sample ready to be tested.

Given a drug and a reagent, the composition and chemical structure of the microcrystal formed is extremely useful to know when it comes to choose the best concentration to be used for the test. Indeed, knowing the molecular/atomic ratio between drug and reagent allows evaluating the order of magnitude in which the reagent is incorporated into the crystal, hence avoiding too high reagent concentrations that would lead to the formation of a high density of reagent crystals.

Unfortunately, information on crystal stoichiometry is sparse, although recent work using X-ray diffraction showed that the GHB:Ag<sup>+</sup> molar ratio was 2:2 in the microcrystal formed between silver (I) and GHB.<sup>(9)</sup>

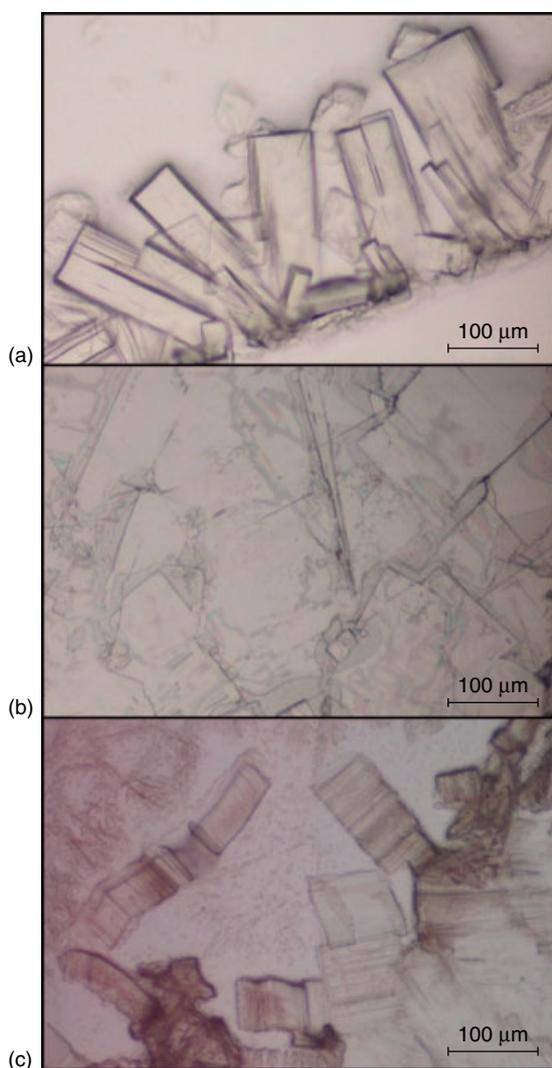
### 3.3 Crystal Growth

The formation of a crystal starts with an event called nucleation, which is the beginning of the transition from liquid phase to solid phase. Nucleation begins when the concentrations of the drug and the reagent are sufficient for the molecules to form enough addition products, which will then result in a number large enough to form a protocystal that grows until it reaches a critical size. It then falls out of solution, becoming a microcrystal, which continues to grow.

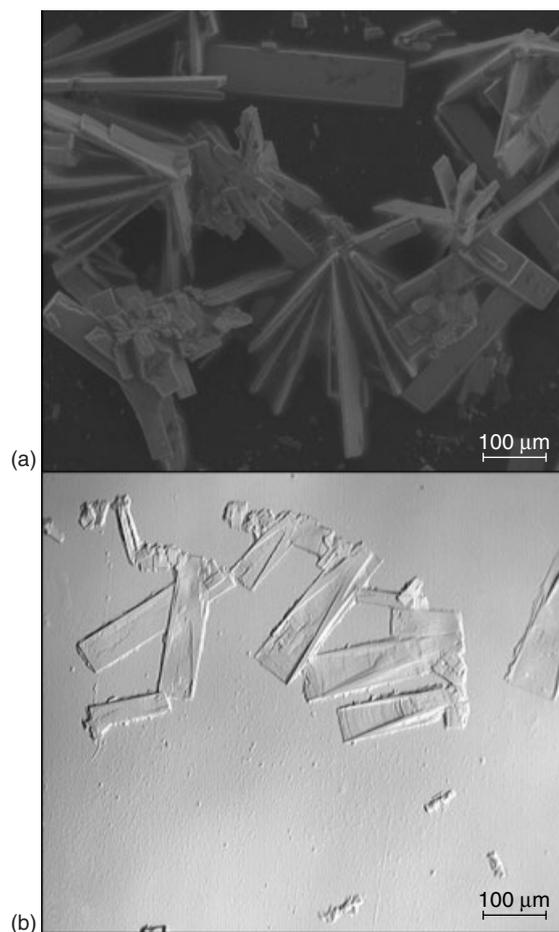
In the context of microcrystalline testing, nucleation can be unassisted: the nucleation sites such as surface of the liquid, suspended impurities, and minute gas bubbles occur naturally. In the case of assisted nucleation, crystal nucleation is encouraged by introducing a solid into the

solution or scoring the microscope slides used for the test with a diamond point.

It is tempting to try to increase the concentration of the molecules in solutions to speed up the nucleation process by applying heat to the test to increase the solvent evaporation rate. However, molecules naturally try to position themselves to achieve the closest packed space because it is the configuration that requires the lowest energy to maintain inducing the most stable state. For microcrystalline tests relying on shape comparison, it is essential to allow time for the molecules to complete this proper packing so that the properly developed



**Figure 2** Drying speed effect on crystal shape. (a) Typical elongated right-angled GHB + lanthanum/silver nitrate microcrystals allowed to grow at room temperature. (b) The same microcrystals after gently blowing hot air on the test area during the analysis are distorted, extremely thin, and are all merged together. (c) The same microcrystals after positioning the slide on a hot plate throughout the experiment are malformed and do not show any right angles.



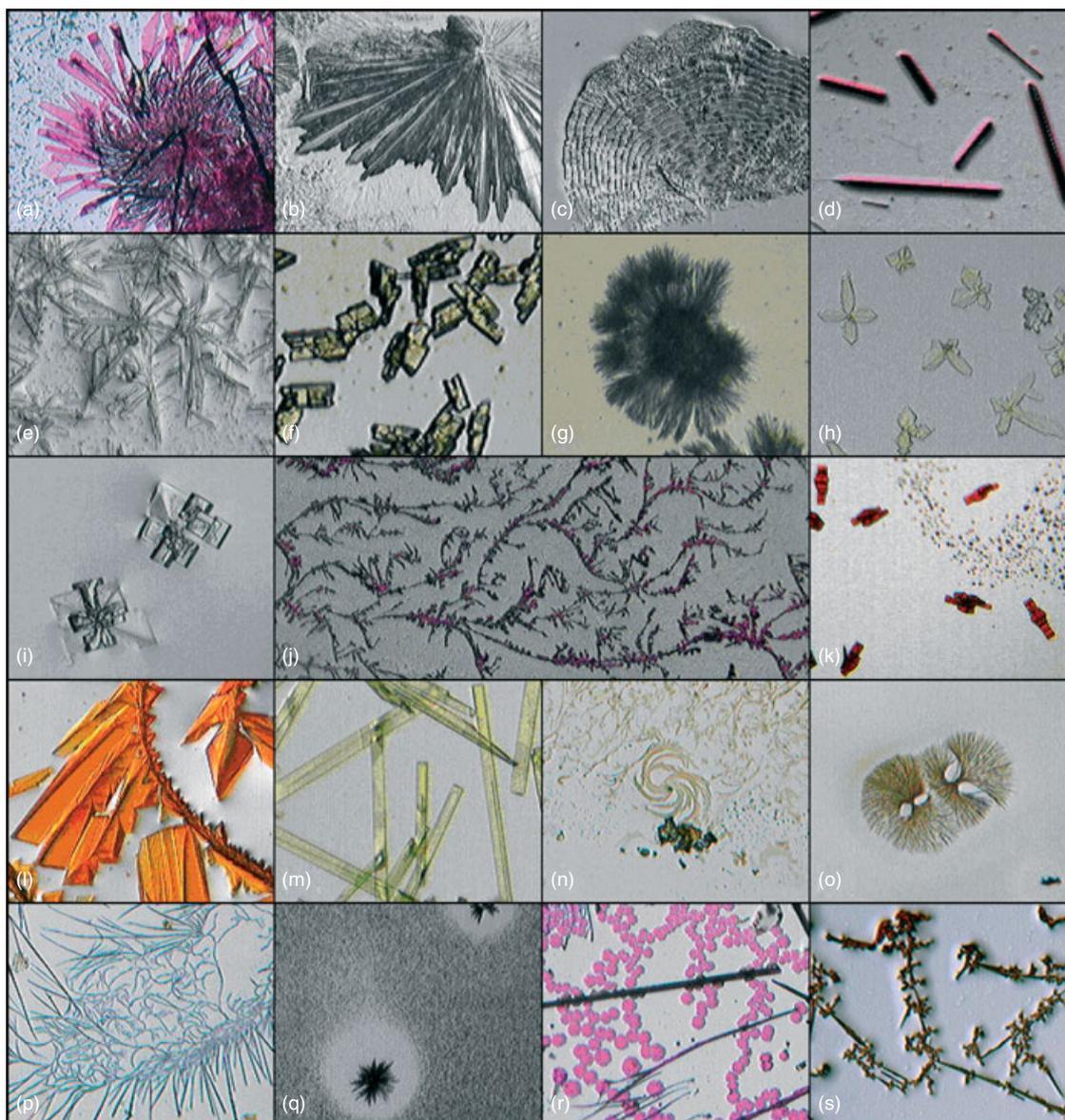
**Figure 3** Support surface tension effect on microcrystal spatial configuration. (a) GHB + lanthanum/silver nitrate microcrystals developed on a SEM carbon stub; (b) the same microcrystals grown on a generic glass slide.

microcrystals can be observed. This is why speeding up the drying process is not advised because it will induce distortions and malformations of the crystals (Figure 2).

The different surface tensions of support surfaces used to develop the crystals, impact on the spatial arrangement of the crystals. Typically, microcrystalline tests are carried out on generic microscope glass slides that are slightly hydrophilic. This type of surface tends to favor the horizontal spreading of microcrystals clusters. On the contrary, a hydrophobic surface such as a scanning electron microscope (SEM) carbon stub encourages the microcrystal clusters to bloom vertically (Figure 3).

### 3.4 Crystal Classification and Description

Crystals can be classified according to their chemical/physical properties. Within this classification, crystals fall within four categories: covalent crystals (e.g. diamond), metallic crystals (e.g. metallic titanium crystal),

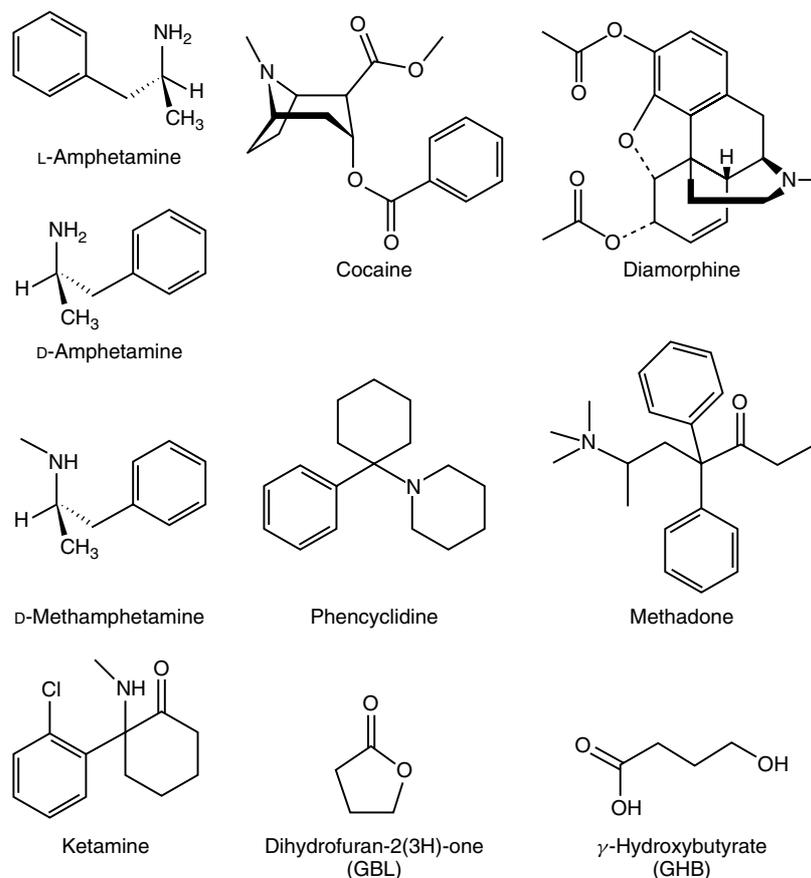


**Figure 4** Examples of microcrystalline structures. (a) Dendrites; (b) tufts; (c) stairs; (d) rods; (e) bundles; (f) prisms; (g) brushes; (h) X's; (i) clusters of prisms; (j) wires/feathers; (k) spindles; (l) skeletons of blades; (m) Blades; (n) spirals of feathers; (o) fans; (p) hairs; (q) rosettes of needles; (r) disks/globes; (s) skeletons of needles.

ionic crystals (e.g. sodium chloride), and molecular crystals (e.g. sugar). Usually, microcrystals created during a microcrystalline test are ionic and molecular crystals: the units composing the crystal are drug molecules and metal ions. The internal order of the crystal is dictated by how the drug molecules arrange themselves around the metal ions and how these addition products further position themselves relative to each other.

A forensic analyst records the crystalline structure to describe the crystal obtained with a test. Both Fulton and Clarke suggested descriptive terms to depict microcrystals; however, they both agree that the descriptions

cannot be exact as different forms overlap. For example, a needle becomes a blade when it is broad enough, and a blade transforms into a plate when length and width are similar. The spatial arrangement of the microcrystals related to each other is also recorded if characteristic, such as rosettes, clusters, and fans. Because the shape, size, color, and spatial arrangement of microcrystals obtained for the sample need to perfectly match the control microcrystals for a positive identification, micrographs are a far superior mean to record microcrystalline test results than a written description. Examples of crystalline structure can be seen in Figure 4.



**Figure 5** Chemical structures.

### 3.5 Storage, Shelf Life, and Sample Recovery

The interpretation of the test is generally performed before complete drying because as the solvent level decreases, more and more reagent crystals form, interfering with the analyst's observations. However, specific microcrystals can often still be observed at this stage, especially when using low concentrations of reagents. Once the test drop is entirely dry, the shelf life of the resulting crystals varies depending on the reagent and the sample itself. Over time, microcrystals degrade and their shapes change, making it impossible to interpret them correctly. For the preservation of the crystals for a prologed period of time, if required, Clarke describes a procedure using the hanging microdrop technique to perform the microcrystalline test (which consists in depositing the microdrop on a glass cover slip and positioning it upside down on a cavity slide to minimize the evaporation rate) followed by the application of a sealing agent, bitumen in toluene, to enclose the cavity and prevent evaporation.<sup>(6)</sup> He claims that the slide may be preserved for several months with this technique; however, bitumen contains heavy metals and could interfere with the test. Alternative substances

with low gas permeability, such as ceramic-based sealant, could be used.

At first glance, the microcrystalline test technique seems destructive, which is always a problem when dealing with minute amounts of sensitive, potentially incriminating material. This is a misconception because the chemical reactions occurring during a microcrystalline test are addition reactions involving only the creation of ionic bonds between the drug and the reagent (Section 3.1). It is possible to recover the sample by redissolving the crystal formed using an adequate solvent and using this extract for further analytical investigations because the molecule was unaltered during the microcrystalline test.

## 4 APPLICATION EXAMPLES

The chemical structures of the drugs discussed in this section can be found in Figure 5.

### 4.1 Cocaine

Three main microcrystalline tests exist for cocaine. The first two use 5% gold chloride or 5% platinum chloride as

reagent and require the sample to be dissolved in 10% acetic acid or HCl.<sup>(12–15)</sup> The characteristic microcrystals expected to be seen are serrated needles with gold chloride and thin needlelike branched skeletons with platinum chloride. Both show immediate precipitation throughout the test on application of the reagent on the sample droplet, resulting in difficulties in finding the crystals of interest.

Alternatively, 1% gold bromide reagent can be used to microcrystalline test for cocaine.<sup>(5)</sup> The sample is dissolved in concentrated sulfuric acid and 10% acetic acid (1:1). On application of the reagent, instantaneous precipitation occurs and very distinct characteristic X's with ragged blade arms and pale orange tint microcrystals start to grow on the periphery of the test area (Figure 6).

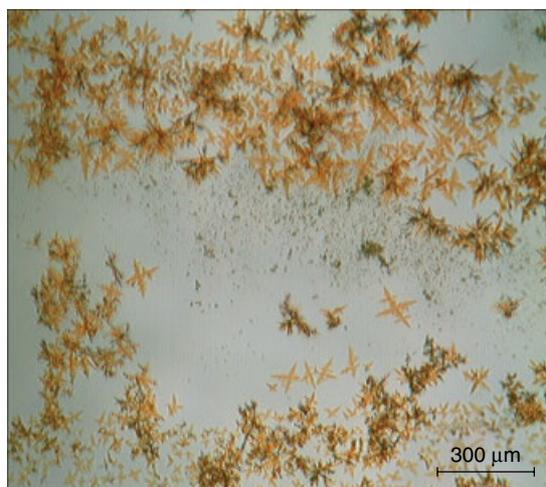
#### 4.2 Diamorphine (Heroin)

Diamorphine is dissolved in 10% hydrochloric acid and microcrystalline tested using 1% mercuric chloride,<sup>(5,6)</sup> or 1% mercuric iodide,<sup>(5)</sup> both resulting in dendritic crystal formations. However, the mercuric chloride shows small dark dendrites with thin branches, whereas mercuric iodide induces dendritic stems (Figure 7).

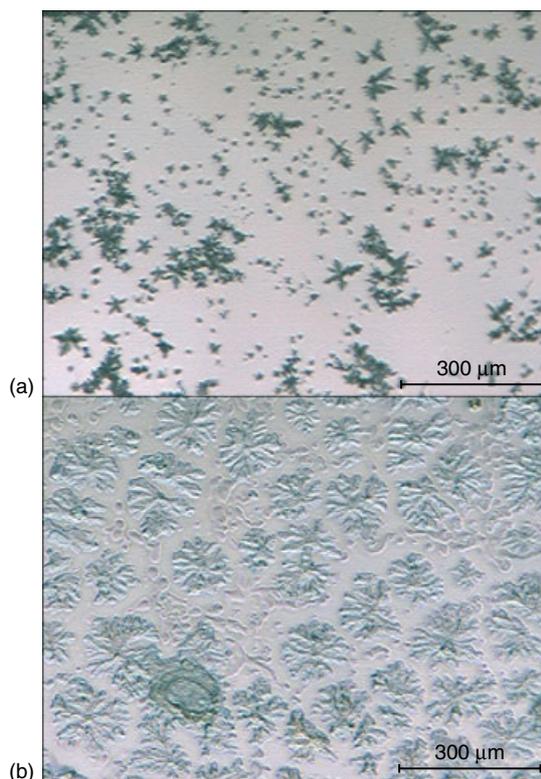
This example demonstrates that different halogens can provoke divergences in the microcrystal shape, although retaining an identical spatial configuration.

#### 4.3 Methadone

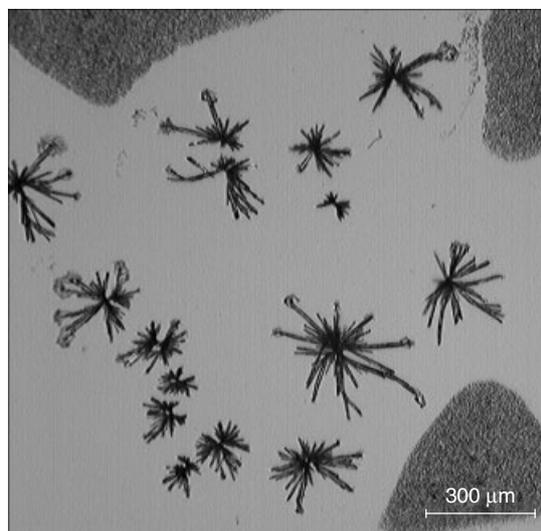
The sample is dissolved in water and 1% mercuric chloride is applied.<sup>(6)</sup> Initially, the test area shows a uniform cloud of dark particles in suspension. Over time, characteristic rosettes of branching rods appear and grow, consuming the cloud (Figure 8).



**Figure 6** Cocaine + gold bromide microcrystals.



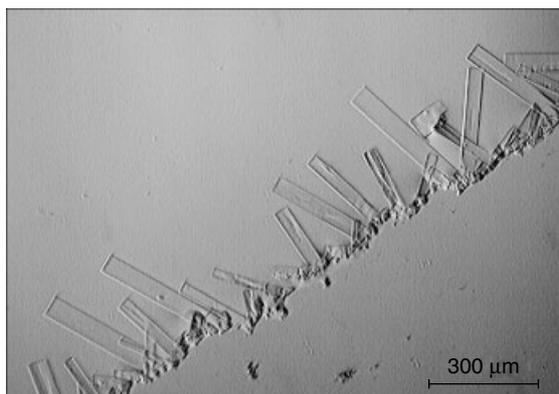
**Figure 7** (a) Diamorphine + mercuric chloride microcrystals and (b) diamorphine + mercuric iodide microcrystals.



**Figure 8** Methadone + mercuric chloride microcrystals.

#### 4.4 $\gamma$ -Hydroxybutyrate

$\gamma$ -Hydroxybutyrate readily dissolves in water and a 1% lanthanum/silver nitrate reagent is applied on the sample droplet.<sup>(9,10)</sup> Specific right-angle microcrystals appear after a few minutes, initially on the edge of the test area (Figure 9).



**Figure 9** GHB + lanthanum/silver nitrate microcrystals.

#### 4.5 Ketamine

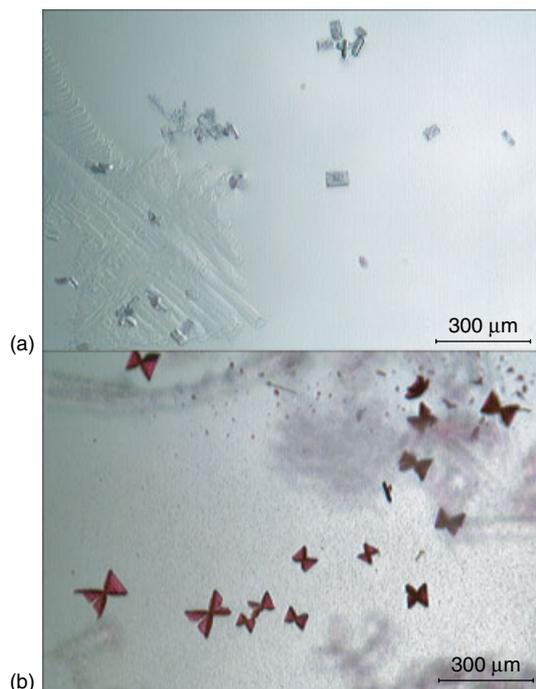
The sample is dissolved in water and 5% platinum iodide reagent is applied.<sup>(6)</sup> Instantaneous precipitation is observed and characteristic rhomboidal plates can be observed fixed on the slide below a layer of reagent crystals suspended in the liquid (Figure 10).

#### 4.6 Phencyclidine

The reagent of choice for phencyclidine microcrystalline test is potassium permanganate.<sup>(6,14,16)</sup> When the sample



**Figure 10** Ketamine + platinum iodide microcrystals.



**Figure 11** PCP + 0.2% potassium permanganate microcrystals. (a) Solvent: 10% HCl and (b) solvent: 10% acetic acid.

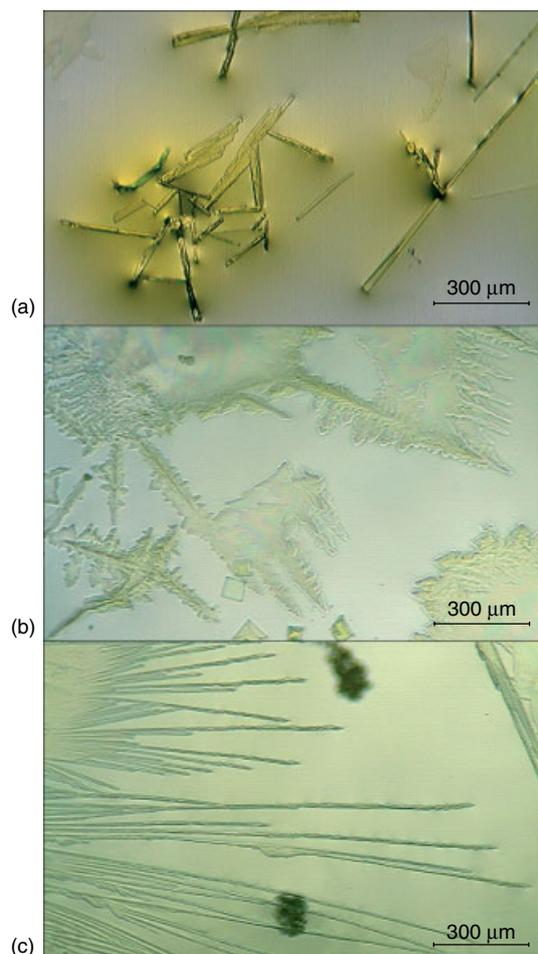
is dissolved in 10% HCl and tested with 2% potassium permanganate in 0.5% phosphoric acid, instantaneous precipitation occurs and the test area is too highly populated by reagent crystals to be able to distinguish the characteristic purple razor-blade-shaped microcrystals expected. Lowering the reagent concentration to 0.2% helps obtain a readable test, although the small crystals obtained appear pale and often misshaped (Figure 11).

Dissolving the sample in 10% acetic acid using the 0.2% potassium permanganate reagent greatly improves the test and very distinctive deep purple razor blade microcrystals form (Figure 11).

#### 4.7 Amphetamines and Methamphetamine

Amphetamine and methamphetamine are chiral molecules. Being able to distinguish between single enantiomers and racemic mixtures is often important for police investigation because it permits the discrimination between clandestine and genuine production products. Typically, clandestine manufacture results in racemates, whereas asymmetric synthesis techniques used by pharmaceutical companies produce mostly dextro compounds.

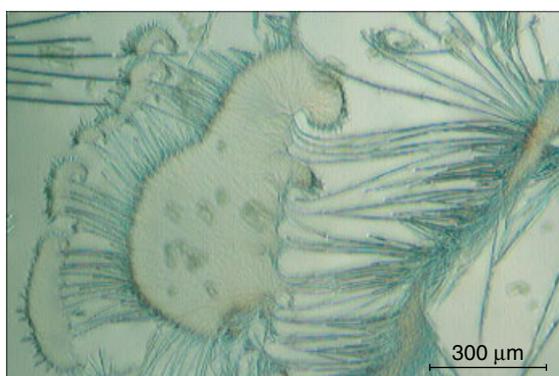
The sample is dissolved in concentrated phosphoric acid and tested with 5% gold chloride reagent.<sup>(17)</sup> The D-amphetamine produces yellow rods and blades after 10 min, whereas the DL-amphetamine shows growing irregular blades with serrated edges instantaneously.



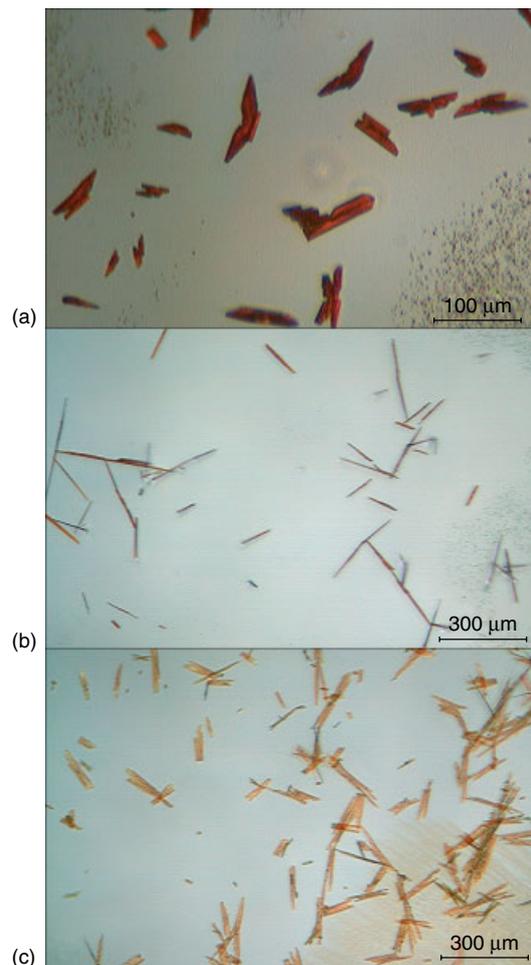
**Figure 12** Gold chloride reagent. (a) Microcrystals formed with D-amphetamine; (b) microcrystals formed with DL-amphetamine; (c) microcrystals formed with D-methamphetamine.

The D-methamphetamine produces long blades of joined crystals within 1 min (Figure 12).

Using 5% platonic chloride as the reagent, D-methamphetamine instantaneously generates grains with



**Figure 13** D-methamphetamine + platonic chloride microcrystals.



**Figure 14** Gold bromide reagent. (a) Microcrystals formed with D-amphetamine; (b) microcrystals formed with DL-amphetamine; (c) microcrystals formed with D-methamphetamine.

sharp edges, which aggregate into skeletal ferns over time (Figure 13).<sup>(17)</sup>

Alternatively, the sample is dissolved in a mixture of concentrated phosphoric and sulfuric acid and 1% gold bromide reagent is applied.<sup>(5)</sup> D-amphetamine produces characteristic small red trapezoidal blades, DL-amphetamine forms small red cigars, and D-methamphetamine shows pale orange, segmented, squared-cut, elongated crystals (Figure 14).

These tests demonstrate the high discrimination power of microcrystalline tests when trying to differentiate between enantiomers and racemic mixtures. This is because of the mechanism by which the microcrystals are formed. The addition complexes pack in a specific preferential manner depending on their physical and chemical properties, ending up in a unique characteristic form. This is corroborated by the differences between D-amphetamine and D-methamphetamine results.

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## ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
CPS	Convention on Psychotropic Substances
DFSA	Drug Facilitated Sexual Assault
FTIR	Fourier Transform Infrared Spectroscopy
GBL	$\gamma$ -Butyrolactone
GC/MS	Gas Chromatography/Mass Spectrometry
GHB	$\gamma$ -Hydroxybutyrate
LC/MS	Liquid Chromatography/Mass Spectrometry
LLE	Liquid-liquid Extraction
LSD	Lysergic Acid Diethylamide
MDMA	3,4-Methylenedioxyamphetamine
PCP	Phencyclidine
SCND	Single Convention on Narcotic Drugs
SEM	Scanning Electron Microscope
SPE	Solid Phase Extraction
TLC	Thin Layer Chromatography

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