جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بابل
كلية العلوم / قسم الفيزياء

الكشف عن تعاطي المخدرات في اثر طبعة الاصبع باستخدام طرق التحليلات الطيفية

رسالة مقدمة الى

مجلس كلية العلوم – جامعة بابل

وهي جزء من متطلبات نيل درجة الماجستير في علوم الفيزياء

من قبل

فاطمة محمد جاسم نجم

(بكالوريوس علوم فيزياء 2015)

إشراف

الاستاذ

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1444 هـ **2022م**

Republic of Iraq
Ministry of Higher Education and Scientific Research / University of Babylon
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Detection on the Drugs Abuse in Fingerprint Trace Using Spectroscopic Analysis Methods

A Thesis Submitted to the Council of College of Science, University of Babylon in Partial Fulfillment of the Requirement for Degree of Master of Science in Physics

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2022 A.D **1444 A.H**

(اللَّهُ نُورُ السَّمَاوَاتِ وَالْأَرْضِ مَثَلُ نُورِهِ كَمِشْكَاةٍ فِيهَا مِصْبَاحٌ الْمِصْبَاحُ فِي زُجَاجَةٍ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ دُرِّيٌّ يُوقَدُ مِن شَجَرَةٍ مُّبَارَكَةٍ زَيْتُونِةٍ لَّا شَرْقِيَّةٍ وَلَا غَرْبِيَّةٍ يَكَادُ زَيْتُهَا يُضِيءُ وَلَوْ لَمْ تَمْسَسْهُ نَارٌ نُّورٌ عَلَى نُورٍ يَهْدِي اللَّهُ لِنُورِهِ مَن يَشَاءُ وَيَضْرِبُ اللَّهُ الْأَمْثَال لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ)

صدق الله العلي العظيم

سورة النور: الآية (٣٥)

Dedication

To

Whom I missed her presence in my life years ago, but she is always present in my heart My older sister

(May God have mercy on her soul)

To

My small family (husband and daughter)… *with a lot of love*

My big family (dad, mom, brothers and sisters)... *with my love and respect*

My Professor… *With my grateful for her teaching*

My friends… *For their Support and encouragement*

Fatima

Acknowledgments

First of all, I should thank my god (Allah) for helping me in completing my thesis, prayer and peace be upon the best of his creation Mohammed and his progeny and companions.

I would like to express my thanks and gratitude to my teacher **Dr. Samira Adnan Mahdi** for suggesting this topic and her extensive knowledge and passion for science helped me to develop my understanding and my inspiration in carrying out this research and extinguished efforts, sound advice and directions that have helped in smoothing out every difficulty encountered during my work.

I would like to express my thanks to the Babylon Governorate Police Directorate, the Laboratory of the Criminal Evidence Investigation Department, as well as to the Ministry of Science and Technology, especially the workers in the Materials Laboratory, the service laboratory of Anwar Al-Razi Company, and the General Directorate for Combating Narcotics and Psychotropic Substances for everything they gave me on this trip.....to you all my appreciation and gratitude.

Many thanks to the deanery of the College of Science in University of Babylon and the Department of Physics for offering me the opportunity to complete my thesis.

Fatima

Supervisor Certification

I certify that this thesis titled (**Detection on the Drugs Abuse in Fingerprint Trace Using Spectroscopic Analysis Methods**) was prepared by (**Fatima Mohammed Jasim Najem**) under my supervision at Department of Physics, College of Sciences, University of Babylon, as a partial fulfillment of the requirements for the degree of master of science in physics.

Signature:

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Date: / 11 / 2022

Certification of the Head of the Department

In view of the available recommendation, I forward this thesis for debate by the examination committee.

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Address: Head of Department of Physics - College of Science – University of Babylon

Date: / 11 / 2022

Summary

In this work, a spectral study was presented to detect drug abuse in fingerprint, as this research deals with a phenomenon that has become common in our social reality now. Three samples were used (amphetamine, methamphetamine and tramadol), and these samples were prepared in two forms (powder and fingerprint), where a gas chromatography device for mass spectrometry (GC-MS) and Raman spectrometry were used to examine the samples of narcotic substances, where fingerprints were examined before and After contamination with anesthetic powder.

The results obtained from the (GC-MS) device showed a clear difference between the spectrum of the pure fingerprint and the spectrum of the contaminated fingerprint, as well as there was a clear match between the spectrum of powder and the fingerprint for a same sample, and different matching ratios appeared between the spectrum of the real samples stored in the device and the spectrum of the same samples that They were examined, as the highest match percentage was in the amphetamine powder sample (83%), and the lowest match percentage was in the methamphetamine powder sample (64%).

From this we conclude that the GC-MS device is sensitive to a small amount of drugs and can be used to detect them in fingerprints.

Samples of the powder of these substances, as well as fingerprints contaminated with the powder of those substances, were also examined by Raman spectroscopy. The spectrum of the two samples does not show any difference and the amount of the substance does not constitute an obstacle to the measurements, which means that Raman can be sensitive to a small amount of substances.

الخلاصة:

تم في هذا العمل تقديم دراسة طيفية للكشف عن تعاطي المخدرات في اثر طبعة الأصبع, حيث ان هذا البحث يعالج ظاهرة اصبحت شائعة في واقعنا الاجتماعي الان. تم استخدام ثلاث عينات هي (الامفيتامين والميثامفيتامين والترامادول), وتم تحضير هذه العينات على شكلين (باودر وبصمة اصبع), حيث تم استخدام جهاز الكروماتوغرافيا الغازية لقياس الطيف الكتلي (GC-MS) وكذلك مطياف رامان لفحص عينات المواد المخدره, حيث تم فحص البصمات قبل وبعد التلوث بمسحوق التخدير.

أظهرت النتائج التي تم الحصول عليها من جهاز (GC-MS) فرقًا واضحًا بين طيف البصمة النقية وطيف البصمة الملوثة, كذلك كان هناك تطابق واضح بين طيف الباودر والبصمة للعينه الواحده, كما ظهرت نسب تطابق مختلفة بين طيف العينات الحقيقي المخزن بالجهاز وطيف نفس العينات التي تم فحصها, حيث كانت اعلى نسبة تطابق في عينة باودر الامفيتامين (83%), واقل نسبة تطابق كانت في عينة باودر الميثامفيتامين (64%).

من هذا نستنتج أن جهاز (GC-MS) حساس لكمية صغيرة من الأدوية ويمكن استخدامه للكشف عنها في بصمات الأصابع .

كذلك تم فحص عينات من مسحوق هذه المواد المخدره ، وكذلك بصمات الأصابع الملوثة بمسحوق تلك المواد بواسطة مطياف رامان, لا يُظهر طيف العينتين أي فرق ولا تشكل كمية المادة عقبة أمام القياسات ، مما يعني أن رامان يمكن أن يكون حساسًا لكمية صغيرة من المواد .

List of Acronyms

Acronym	TITLE
AMP	AMPHETAMINE
ATC	Anatomical Therapeutic Chemical
CCD	Charge Coupled Device
FDA	Food Drug Administration
FT-Raman	Fourier Transform- Raman
GC-MS	Gas Chromatography–Mass Spectrometry
IR	Infrared Raman
MAMP	METHAMPHETAMINE
RS	Raman Spectroscopy
TR	Tramadol

List of Symbols

Symbols	TITLE
ω_0	frequency of incident light
ω_1	the molecular electronic absorption frequency
ω_v	the vibrational frequency
ΔE	detuning energy
ωs	the frequency of the scattered photon
ω	angular frequency
μ^{ind}	function of the nuclear coordinates
$d\phi$	radiation powe
$d\Omega$	solid angle
σ	the cross sections
I_0	the incident intensity
I_s	the scattered intensity

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1.1 Introduction:

The identification of prohibited substances, especially drugs, is a major concern, as drug abuse causes many and serious problems, it draws people into crime, and destroys lives. The amount of prohibited substances flooding Iraq is enormous, and is expected to increase dramatically in the future.

The use of fingerprints to identify people is becoming routine, as this method is of value all over the world. Some people don't realize that the use of rough skin impressions as a form of identification dates back thousands of years and has been practiced in a variety of cultures. Fingerprints have been used to confirm identity in China since 300 B.D, Japan since 702 A.D, and the United States since 1902 A.D [1,2].

The hyphenated analytical technique Gas Chromatography–Mass Spectrometry (GC-MS) combines the separation capabilities of gas-liquid chromatography with the detection feature of mass spectrometry to identify distinct compounds within a test sample. The volatile and thermally stable substitutes in a sample are separated by GC, whereas the analytics is fragmented by GC-MS and identified by its mass [3,4].

Raman spectroscopy, which is closely connected to IR spectroscopy, is a technique for detecting vibrations in molecules [5].

In the Raman experiment, a laser light source is employed to irradiate a substance. The bulk of light is elastically dispersed at the light source's wavelength (Rayleigh scattering), while a tiny portion of the radiation that is emitted (about 5-10 %) is spread out at a different energy level (Raman scattering) . Vibrations of molecules represented by difference in energy between Raman emission and incident source.

While Infrared spectroscopy has traditionally a lot more widely utilized compared to Raman spectroscopy, in many applications, advances in Raman instrumentation have made it the technique of choice [6].

In this work, the effect of amphetamine, methamphetamine and tramadol on fingerprints was examined using spectroscopic methods (Raman spectroscopy and gas chromatography-mass spectrometry).

1.2 The Gas Chromatography–Mass Spectrometry

Gas chromatography-associated mass spectrometry (GC-MS) is an effective method for the separation and detection of volatile organic compounds and gaseous mixtures of various inorganic compounds. It is a useful technology that was first discovered in 1940 AD, when it was later introduced as an essential tool used in many laboratories. He presented a clear technical development in the field of systems and electronics. The use of a mass spectrometer as a detector in gas chromatography was developed during the 1950 A.D by James and Martin in 1952 A.D [7].

Gas chromatography-related mass spectrometry is so important that it has been used in most industries: medical, environmental, pharmaceutical, chemical, food science and many other fields. Identify the different materials in the test sample [8].

GC-MS applications include drug detection, fire investigation, environmental analysis, investigation, explosive detection and identification of unknown samples, GC-MS can also be used in airport security to detect items in baggage or on humans [9].

1.3 Raman Spectroscopy

Raman spectroscopy has been invented by Raman and Krishnan in 1928, when they observed inelastic light scattering phenomena. As the monochromatic light incident on the material most of the scattered light includes radiation of the incident frequency (Rayleigh scattering). In addition, a tiny amount 10^{-4} of photons with shifted frequency is recorded. Stokes scattering is the fraction of photons scattered from molecular centers with less energy than they had before the interaction. The anti-Stokes scattered photons have greater energy than those of the exciting radiation. An associated molecular vibration and rotational energy changes measure by infrared (IR) and Raman spectra [10].

To obtain the Raman spectra two machineries are used: dispersive Raman and Fourier transform Raman (FT-Raman). Both have different lasers and different analyzed and scattered methods.

In the confocal Raman spectroscopy, the laser light that emerge from the probe-head is focused onto a diffraction- limited spot in the sample using the microscope objective. The backscattered Raman signal is relocated onto a small confocal aperture that acts as a spatial filter, leaving the Raman signal strengthened at the beam waist, but disregarding Raman constructed at other points above and below the beam waist. The filtered Raman signal then proceeds to the spectrometer where it is diffused onto a (charge coupled device) CCD camera to generate a Raman spectrum (RS) [11].

1.4 Literature Survey

We will review the literature study for some authors:

- **In (2010), Ping Hei Ronnie, *et al*. [12]** studied the FTIR and Raman spectral imaging can be used to simultaneously image a latent fingerprint and detect exogenous substances deposited within it. These substances might include drugs of abuse or traces of explosives or gunshot residue. In this work, spectral searching algorithms were tested for their efficacy in finding targeted substances deposited within fingerprints.
- **In (2012), Pompi Hazarika, *el at*. [13]** studied fingerprints have been used in forensic investigations for the identification of individuals since the late 19th century. However, it is now clear that fingerprints can provide significantly more information about an individual. Here, we highlight the considerable advances in fingerprinting technology that can simultaneously provide chemical information regarding the drugs ingested and the explosives and drugs handled by a person as well as the identity of that individual.
- **In (2015), Elphine Cappelle, *el at.* [14]** studied detection and quantification of drugs of abuse and pharmaceuticals in nails, methods for nail analysis are based on gas chromatography (GC) coupled to mass spectrometry (MS) Morphine , heroin, as well as codeine and hydrocodone were analyzed in toenails of 34 cocaine users However, only a few samples tested positive for pioids. Three cases showed the presence of morphine (range 0.16–0.72 ng/mg) , two of which were positive for codeine (1.02 and 3.07 ng/mg) and one for hydrocodone (0.62 ng/mg).

- **In (2016), De Oliveira Penido, *et al.* [15]** studied the Current forensic methods for detecting and identifying cocaine and other drugs of abuse are destructive, so evidence cannot be re-analyzed. Raman spectroscopy, based on inelastic light scattering, allows for rapid, inexpensive and nondestructive analysis in forensic science. This review presents the state-of-the-art use of Raman spectroscopy as a confirmatory method for the identification of cocaine and other drugs of abuse in seized samples, including hidden compounds in legal materials such as beverages and clothes, among others, used for trafficking.
- **In (2017), Catia Costa, *el at.* [16]** studied the possibility of using surface mass spectrometry for the detection and quantification of drugs of abuse in latent fingerprints. optimized method included full scan mass spectrometry measurements (quantitative) followed by tandem mass spectrometry (MS/MS) scans (qualitative) for the detection of cocaine, (159) individual fingerprint samples (collected from individuals seeking treatment for substance abuse) were analyzed with a (99%) true positive rate through the detection of either cocaine. Cocaine, were found in fingerprints produced by contact, showing that the presence of a cocaine metabolite in a fingerprint Furthermore, secondary transfer scenarios showed that cocaine could be transferred through handshakes.
- **In (2017) Ragaa Talaat Said, *et al.* [17]** studied the Drug abuse is considered a major contributor to both medical morbidity and mortality all over the world. It also represents an important health problem that has a great impact on the person's life both socially

and economically. A few methodologies have been created for the identification of drugs of abuse "for example liquid chromatography-mass spectrometry (LC-MS). The aim of this work was to assess the possibility of detection of some drugs of abuse from fingerprints using LC-MS.

- **In (2018), Khanda Sammy, *et al.* [18]** studied the identification of body fluid (BF) stains at a crime scene is an important step of a crime scene investigation since traces of BFs are typically the main source of DNA evidence. Raman spectroscopy is a new emerging method for identifying and differentiating between BF stains. As any new analytical method developed for identification and differentiation of classes of materials, it needs to be evaluated for potential environmental interferences (EIs). This study specifically focused on proving that Raman spectroscopy is not susceptible to false positive.
- **In (2018) , Ghada El Galad, *el at.* [19]** study 200 drivers in Fayoum city. The screened drugs were cannabis, benzodiazepine, morphine and tramadol. All samples are screened by do detect studied types of drugs at forensic lab.at Fayoum University and positive samples were confirmed by gas chromatography (G.C) The study showed that 21.5% were drug abusers, 11.5% were Tramadol abusers, 6.5% were tetrahydrocannabinol , and 3.5 Tramadol abusers.
- **In (2020), Yaser Zuhair Tawffeq, *el at.* [20]** studied the possibility of finding amphetamine, methamphetamine, and cocaine in the finger prints of users of these drugs analyzed by

using Raman spectroscopy. The study showed the high sensitivity of Raman apparatus to these substances when used in the form of a pill or in the form of powder weighing 165 ml. It also showed the efficiency of the Raman device to measure the spectrum of amphetamine methamphetamine and cocaine, which was obtained to match what, is in the library of the device with the three types of drugs. Finger prints were also examined for a group of drug addicts in prisons and six cases per drug were studied. The readings showed a rough match with the pure substances of the drug.

- **In (2021), Kumar and Pardeep, *et al.* [21]** studied the Spectroscopy with its advances in technology is centralized to novel applications in the detection of abused drug substances and clinical toxicology. These techniques have attracted growing interest as forensic tools for the early detection and monitoring of exploited drugs. This review describes the principle, role, and clinical application of various spectroscopic techniques which are utilized for the identification of drug abuse like morphine, cocaine, codeine, alcohol, amphetamines, and their metabolites in whole blood, plasma, hair, and nails.
- **In (2022), Mohamed Amin, *et al.* [22]** studied Raman spectroscopy combined with multivariate statistical analysis was used for the detection and identification of drug traces when of aspirin, ibuprofen, diclofenac, ketoprofen and naproxen have been touched. Partial least squares discriminant analysis of Raman spectra showed an excellent separation The developed classification model was externally validated using by a new donor

and showed 100% accuracy. Study demonstrated the great potential of Raman spectroscopy in the chemical analysis and the detection and identification of drug traces in particular.

1.5 Aims of the Study

The aims of the study are:-

1. Determining the kind of the best and optimal spectroscopic method to obtain the expected measurements.
2. Obtain the spectral region of the drug in the trace of fingerprint to specify the kind of drug.
3. Comparing the sensitivity of the devices used in this study.

2. Introduction:

This chapter is devoted to the description of the basic technology of Raman scattering, as well as a description of the technique of gas chromatography coupled with mass spectrometry.

The other part in this chapter will discuss the morphology of the skin and it's structural. Finally, the characteristics of drugs in general and the definition of some types of drugs under study will be presented.

2.1 Technique of chromatography- mass spectrometry Device (GC-MS)

The Gas chromatography coupled to mass spectrometry (GC-MS) has been regarded as the gold standard for analyzing many compounds (lipids, drug metabolites, and environmental contaminants), as well as for forensic science. One of the advantages of (GC-MS) is that identification of detected species is based on both a retention time and a mass spectrum (a compound's specific fragmentation pattern).

The fragmentation spectra obtained by (GC-MS) are not instrument dependent and allow for the creation of databases and the sharing of data between users, making the technique particularly valuable. In addition, (GC-MS) allows for quantitative detection of analysis. In classical methods, measuring either a single compound or a set of chemically related substances (such as short chain fatty acids or amino acids) [23].

On the one hand, (GC-MS) is far from the ideal, not only is it limited to compounds that either are volatile or can be made volatile through the derivatization process, but also all nonvolatile compounds must be carefully removed from the sample before analysis, which requires demanding sample treatment. In contrast, (GC-MS) is highly sensitive and permits working with standard libraries for identification of detected species, it is widely used [24].

2.2 Work of Raman Spectrometer

The linear and nonlinear optical phenomena in Raman scattering describe the change of the molecular optical properties due to the presence of an electric field. Such interaction can be partly explained by classical theory of light scattering which in some respect can be regarded as a complementary view to a quantum mechanical treatment of light-matter interaction. From the quantum mechanical point of view, light and matter is dual in behavior, meaning that they display in some cases wave nature properties, like in diffraction, whereas at other instances, they show a behavior of particles.

Furthermore, these two complementary views of light as either a classical electromagnetic wave or a stream of photons can be used to describe the Raman Effect, which is a result of inelastic interaction between light and matter. This interaction in turn can generate linear and nonlinear optical phenomena, depending on the strength of the applied electric field and the nature of the sample [25].

For instance, the electric field intensities must be higher than typically 109 V/m to make the contributions of the induced dipole moment large enough to create a nonlinear effect in the medium.

Such high electric field intensities can be reached with the use of giant-pulse lasers. After this short introduction, let first consider linear scattering and in particular the situation when the frequency of incident light (stream of photons) ω_0 is far away from the molecular electronic absorption frequency ω_1 such that $\omega_\nu \ll \omega_0 \ll \omega_1$, where $\omega_\nu$is the vibrational frequency of the molecules illustrate in Eq. (2.1) [11].

$$\tau \Delta E \geq \frac{1}{2}\hbar \qquad (2\text{-}1)$$

Where ΔE is the energy difference between the virtual and nearest resonant state (detuning energy). Now after this virtual absorption, the molecule will return back to its ground state through the process of de-excitation which gives rise to the scattered photon [26].

Moreover, if the frequency of the scattered photon (ω_s) is analyzed, there will in general be a characteristic frequency of the type $\omega_s=\omega_0\pm\omega_\nu$. The new frequencies correspond to so-called Raman bands which collectively represent the normal Raman spectrum of the molecule. The Raman bands at frequencies less (greater) than the incident frequency ω_0.is referred to as Stokes (anti-Stokes) bands [27].

The origin of the Stokes and anti-Stokes scattering may be explained in terms of energy transfer between the incident light (photons) and the scattering system. When the molecule is initially excited to a

level above the ground state, the Scattered photon will gain energy and is termed anti-Stokes scattering $\bar{\hbar}(\omega_0+\omega_v)$.

On the other hand if the molecule is initially at its lowest level (usually the ground state), the scattered photon will lose energy and is termed Stokes scattering $\hbar(\omega_0-\omega_v)$ as shown in Figure 2.1, When the detuning ΔE decreases, the photon energy is large enough ($\omega_1=\omega_0$ +ΔE) to excite the molecule into the electronic state S1 which become absorbing. In this case, the molecular properties such as the polarization become different and require more complex analysis than in the non-resonant case [28].

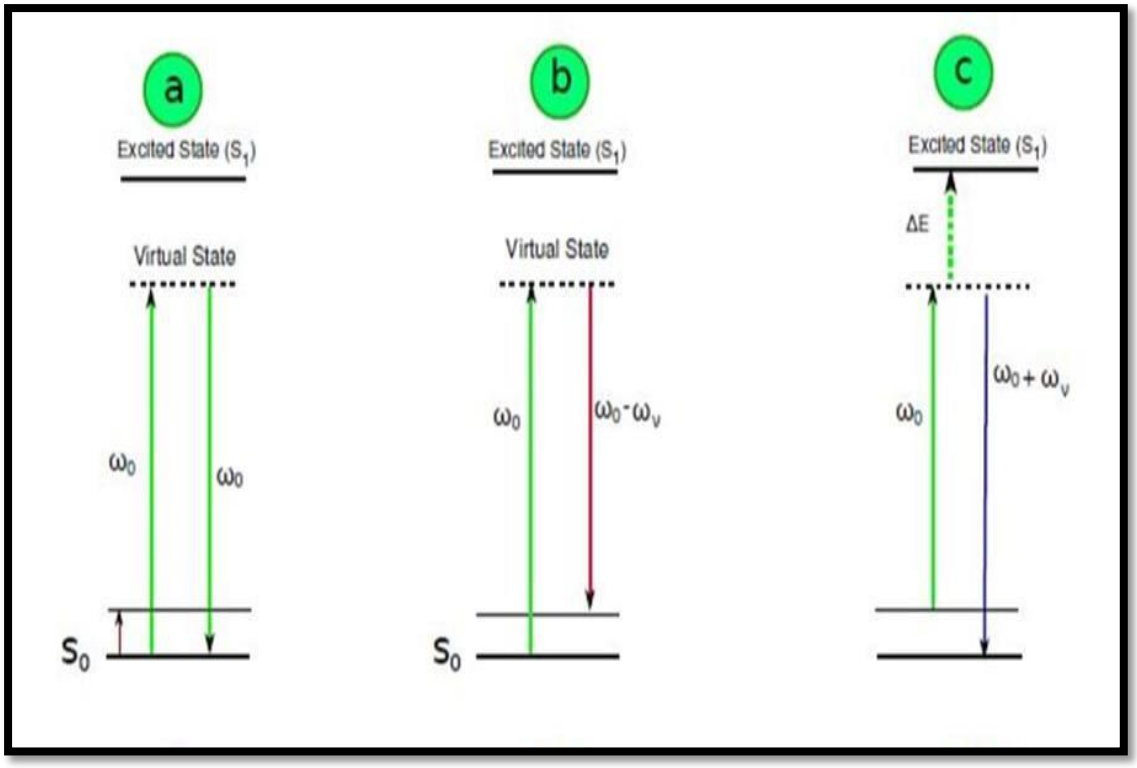


Figure 2.1: (a) Different optical processes of scattering Rayleigh, (b)resonance Raman scattering (Stokes), (c) Non-resonance Raman scattering(anti-Stokes)[27]

2.3 Raman cross sections

Consider a single molecule located at the origin 0 of a space-fixed Cartesian sys- tem X, Y, Z (Figure 2.2). assume that the incident radiation to be a monochromatic non-divergent parallel beam of small cross section (laser excitation), with angular frequency ω, and that the scattered radiation can be observed along a certain direction (non-divergent) beam by arranging the experimental con- dictions [28].

Assume also that the wavelength of the incident radiation *E*is large compared to to the size of the molecule. For instance, the wavelength of light in the visible and ultraviolet regions of the electromagnetic spectrum is of the order of 100 nm, while a typical bond length in a molecule is of the order 1 °A=0.1 nm. Bearing in mind these idealized conditions will consider a common macroscopic experimental setup to have a beam incident in the Z-direction and polarized along the Y -direction. The detection of the Raman scattering intensity is then made in the X-direction ($I_s \propto (\mu^{ind})^2_{fi}$) see Eq (2.2). In this situation the induced polarization oscillating in the Y Z-plane is detected as are sponse to the molecule-radiation interaction and the square amplitude of the polarization becomes [29].

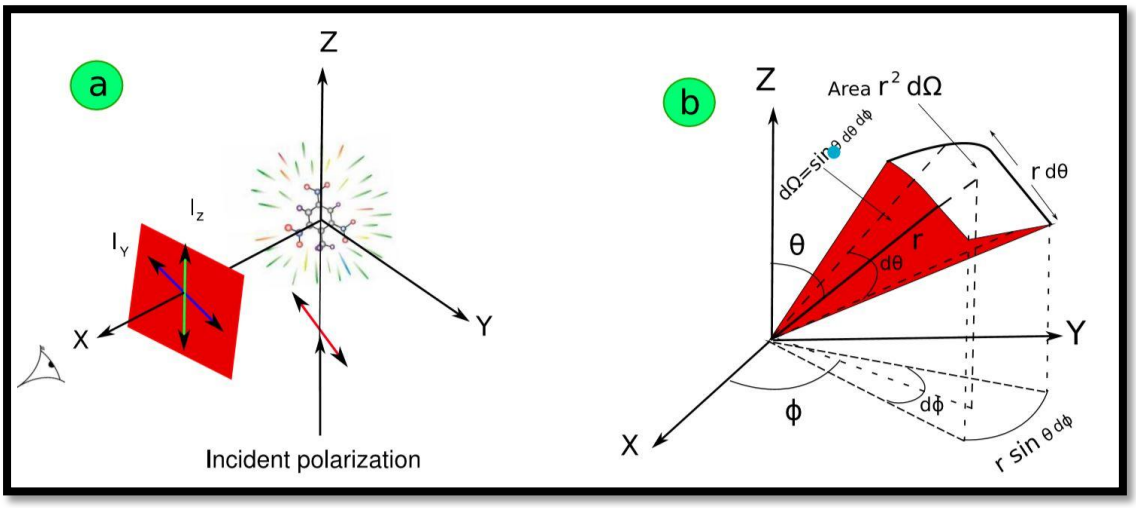


Figure 2.2: (a) Raman scattering from a single molecule: geometry for Z(YZ)X measurement, (b) An element of solid angle dΩ is defined from small section of a surface of sphere of radius r [29].

$$(\mu^{ind})^2_{fi} = [\alpha^{fi}_{yy}(\omega)\mathrm{E}^{w}_{y}\, e^{-iwt} + c.c.]^2 + [\alpha^{fi}_{zy}(\omega)\mathrm{E}^{w}_{y}\, e^{-iwt} + c.c.]^2 \qquad (2\text{-}2)$$

Where $\alpha^{fi}(\omega)$ is the polarizability of the molecule, $\mathrm{E}^{\omega}_{\mathrm{Y}}$ is the amplitude of the electric field and the subscript if denotes a transition moment between the initial and final vibration states and where the integration over electronic coordinates has been carried out so that μ^{ind} is a function of the nuclear coordinates. The over bar indicates that an orientation averaging is to be performed in correspondence with a randomly oriented molecular configuration [30].

The Raman intensity relevant to the above mentioned experimental conditions goes as the ratio of radiation power dϕ in a conical beam of solid angle dΩ (Figure 2.2). The detected radiation is due to the induced polarization in the sample; the expression for its intensity is given by[31].

$$I_S=\frac{d\Phi}{d\Omega}=\frac{\omega_s^4\ (\mu^{ind})_{fi}^2}{32\pi^2\varepsilon_0 c^3}=I_0\frac{d\sigma}{d\Omega} \qquad (2\text{-}3)$$

Where c is the speed of light, ε_0 is the vacuum permittivity and where it is assumed that is increases linearly with the incident intensity ($I_0=\frac{1}{2}c_0\varepsilon_0 E_Y^2$). Furthermore, the cross sections σ. And $\frac{d\sigma}{d\Omega}$ are often given instead of the scattered intensity I_s because they are independent of I_0. The cross section σ. can also be defined as an effective geometrical area of the molecule for removing light from the incident beam , and therefore it has the dimensions of an area. However, for practical reasons, it is preferable to make the measurement of the scattered light in a certain direction with a limited acceptance angle as indicated before, thus differentiate the cross section with respect of the solid angle dΩto become as $\frac{d\sigma}{d\Omega}$ [30].

In this case the spatial distribution (Probability distribution) of the scattered beam can be easily measured by counting the rate at which particles (photons) incident on detectors located at different positions around the target. It is also worthwhile to mention that the cross sections are in fact molecular properties that are dependent upon other experimental parameters [32].

2.4 Outer Morphology of Friction Ridge Skin

The outer morphology of the friction ridge skin is a direct reflection of its function. The ridges and sweat pores allow the hands and feet to grasp surfaces firmly, and the creases allow the skin to flex. Ridges, creases, and mature scars of the friction ridge skin are durable morphological features [32]. Warts, wrinkles, blisters, cuts, and calluses may also appear on the friction ridge skin and are frequently transient morphological features. The anatomy and physiology of a feature determine whether the feature is durable or transient in nature [33]. Figure (2.3) is an image of a left palm displaying the normal morphology of friction ridge skin. The skin is an organ composed of three anatomical layers: epidermis, dermis, and hypodermis [34]. These anatomical layers together function to provide the body with a protective barrier, body temperature regulation, sensation, excretion, immunity, a blood reservoir, and synthesis of vitamin D [35].

The outer layer of skin is the epidermis. The epidermis prevents water loss through evaporation, acts as a receptor organ, and provides a protective barrier for the underlying tissues. Melanocytes, the pigment-producing cells of the epidermis, play a key role in the protective barrier. The pigmentation produced by the melanocytes shields the DNA of the keratinocytes (primary cell type of the epidermis) from the sun's harmful rays. Additionally, the melanocytes are responsible for the synthesis of vitamin D [36].

The dermis is a layer of connective tissue that supports the epidermis. It is a network of cells, fibers, blood vessels, and gelatinous material that provides structural support and nourishment for the epidermis. The dermis serves as a blood reserve and participates in sensory reception and temperature regulation [37].

The only skin appendage of the friction ridge skin is the eccrine sweat gland. Although sweat glands are distributed over almost the entire skin surface, the friction ridge skin has the highest concentration of eccrine glands, 2500–3000/2.5 cm^2 [38]. The sweat glands of the friction ridge skin are also the largest on the body. Eccrine sweat glands participate in temperature regulation by secreting sweat and assist in the excretion of metabolic waste (e.g., urea) [39].

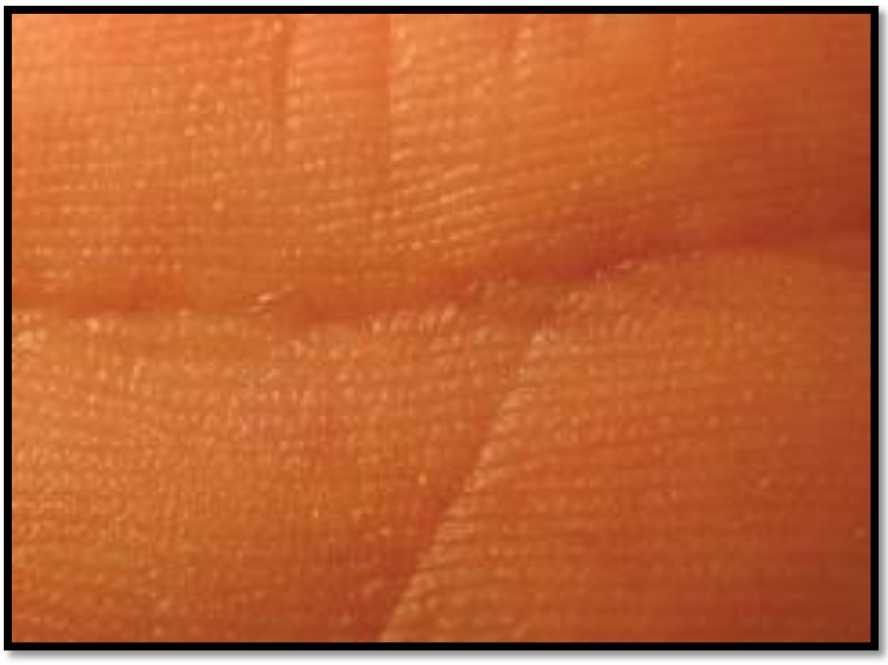


Figure 2.3: Friction ridge skin of the left palm [39].

2.5 Drugs Characterizations

A drug is a substance that causes an amendment in an organism's physiology once consumed [40]. Consumption of medicine is via inhalation, injection, smoking, and ingestion absorption via a patch on the skin or dissolution beneath the tongue [41].

In pharmacological medicine, a drug could be a chemical substance, usually of famous structure, which, once administered to a living organism, produces a biological result [42].

Historically medicine was obtained through extraction from healthful plants [43]. The drugs usually classified into —groups of connected medicine that have similar chemical structures, constant mechanism of action (binding to constant biological target), a connected mode of action, which square measure wont to treat constant illness [44,45].

The Anatomical Therapeutic Chemical system (ATC), foremost wide used drug system, assigns medicine a singular ATC code that is associate in nursing alphamerical code that assigns it to specific drug categories at intervals the ATC system [46]. Where another major system is that the Bio pharmaceutics system, This classifies medicine consistent with their solubility and porosity or absorption properties [47,48].

Psychoactive medicine measure chemical substances that have an effect on the operate of the central systema nervosum, fixing perception, mood or consciousness [49]. This medicine square measure divided into totally different teams like stimulants, antidepressants, anxioly tics, depressants and hallucinogens. These psychoactive medicines are

established helpful in treating a big selection of medical conditions as well as mental disorders round the world. The foremost wide used medicines within the world embody caffeine, plant toxin, and alcohol [50].

Those are thought of recreational medicine since they're used for pleasure instead of healthful functions [51]. Abuse of much mind blowing medicine will cause psychological or physical addiction. Its price noting that each one medicine will have potential facet effects [52].

2.5.1 Amphetamine

This thesis deals with two different kinds of amphetamine-type stimulants, namely amphetamines and methamphetamines: two closely related, but not entirely similar substances. For clarity, a brief description of these terms is provided here [53].

Amphetamine-type stimulants is a catch-all phrase for all amphetamines, cathinones as well as other drugs that resemble amphetamines in their structure or pharmacological action, such as methylphenidate. The word amphetamine is a contraction of α-methylphenethylamine. In the strictest sense of the word, amphetamine refers to the corresponding molecule shown in Figure (2.4).

The phenethylamine part of the word refers to the most basic “backbone” of the molecule consisting of a 6-carbon phenyl ring connected to an amino (NH_2) group by a two-carbon side chain. The carbons in the side chain are referred to as αand βcarbons. The α-carbon, located closest to the amino group, has a methyl ($-CH_3$) group attached to

it, hence the a-methyl part of the name. When referring specifically to this molecule, the abbreviation AMPH will be used in this thesis.

As Figure 2.4 shows, the basic amphetamine structure is not unique to AMPH. The amino group can be methylated and functional groups can be added to numerous locations on the ring and side chain of the amphetamine molecule, producing a vast number of different substances [52].

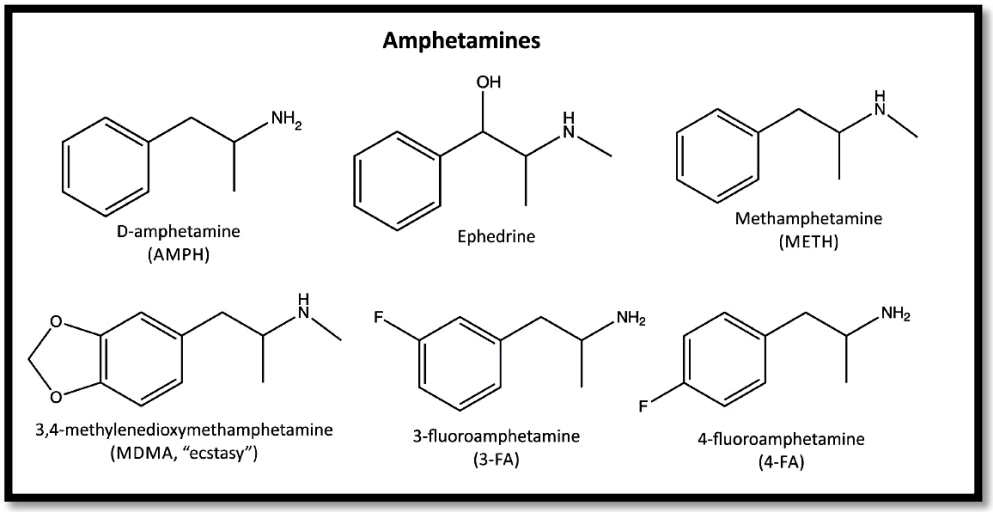


Figure 2.4: Molecular structures of amphetamine-type stimulants [52].

Although amphetamines are used for thousands of years, the chemical synthesis of AMPH may be a more modern event that was initial represented by Rumanian chemist diseased person edeleanu. However, the drug received comparatively very little attention till its psychostimulant properties were discovered many decades later [54].

It was first introduced commercially in 1932 by Smith Franz Kline and French, beneath the brand Benzedrine, as associate degree dispenser for treating respiratory illness and allergies, because it effectively enlarged nasal and cartilaginous tube passages [55].

Once its introduction in pill kind in 1936 it quickly became one of the foremost in style and well-known medicine of all times. Its effects were welcome by people across completely different social strata and skilled teams, starting from stay-at-home moms [56].

The surge in quality rectifier to (AMPH) being regular as a prescription-only medication in 1939, in a shot to decrease its use. However, thanks to aggressive promoting by the pharmaceutical trade – AMPH was marketed for treating something from allergic rhinitis, fatigue and depression, schizophrenia, high demand for the drug its use solely increased [57]. By 1970 the pharmaceutical business created ten billion tablets and it's estimated that 50-90% of this quantity was re-sold or otherwise entertained to the black market [58].

Notably, amphetamines square measure presently still in use by soldiers up till this day [59].

Today, AMPH remains a wide used drug. though the quantity of indications that AMPH is often prescribed has remittent considerably, it still remains one amongst the primary treatments for minimal brain damage, a unwellness poignant up to five of the adult population, with an even higher prevalence in youngsters. Moreover, AMPH is commonly

prescribed off-label for variety of different disorders. Importantly, except for its medical uses, amphetamines also are wide used recreationally [60,61].

In keeping with the international organization workplace on medicine and Crime, amphetamines square measure the second most generally used illicit drug within the world, once cannabis [62].

2.5.2 Methamphetamine

Crystal methamphetamine hydrochloride was 1st synthesized in 1919 by Akira Ogata. Methamphetamine was 1st synthesized from ephedrine in Japan in 1893 by chemist Nagai Nagayoshi [63].

The term "methamphetamine" was derived from components of the chemical structure of this new compound: methyl group alpha-methylphenylethylamine. In 1919, crystallized Methedrine was synthesized by Akira Ogata via reduction of ephedrine exploitation red phosphorus and iodine. In 1943, Abbott Laboratories requested for its approval from the U.S. Food and Drug Administration (FDA) for the treatment of hypersomnia, mild depression, post encephalitic Parkinsonism, chronic alcoholism, cerebral coronary-artery disease, and allergic rhinitis. Methedrine was approved for all of those indications in December, 1944. All of those indication approvals were eventually removed. The sole 2 approved marketing indications remaining for methamphetamine area unit for attention-deficit disorder (ADHD) and also the short management of obesity, though the drug is clinically established as effective within the treatment of narcolepsy [64].

Also known as methamphetamine methyl amphetamine, N-methyl amphetamine, desoxyephedrine, and colloquially as "meth" or "crystal meth", is a psychostimulant of the phenethylamine and amphetamine class of drugs. It increases alertness, concentration, energy, and in high doses, can induce euphoria, and increase libido [65].

Methamphetamine has high potential for abuse and addiction by activating the psychological reward system via triggering a cascading release of dopamine, norepinephrine, and serotonin in the brain. Methamphetamine is FDA approved for the treatment of ADHD and exogenous obesity, marketed in the USA under the trademark name Desoxyn [66]. Shown in Figuer (2.5, 2.6).

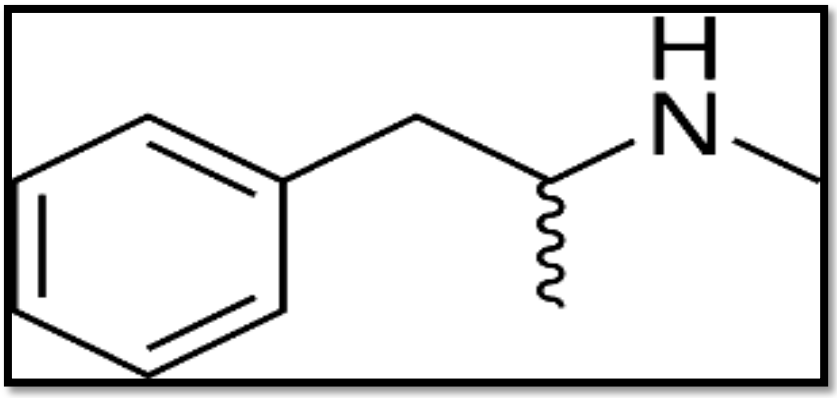


Figure 2.5: The molecular structure of Methamphetamine [66].

Figure 2.6: Crystal methamphetamine was first synthesized in 1919 by Akira Ogata [66].

Chronic methamphetamine abuse could end in prolonged psychiatrical disorders, psychological feature impairment, likewise as AN inflated risk of developing shaking palsy. As results of methamphetamine-induced neurotoxicity to dopaminergic neurons, chronic abuse may additionally result in symptoms that persist on the far side the withdrawal amount for months, and even up to a year [67].

Research has found that 20% of methamphetamine hydrochloride addicts expertise a psychopathy resembling psychosis that persists for extended than six months post-methamphetamine use. In addition to psychological hurt, physical hurt, harm, could occur Methamphetamine

could be a potent central system stimulant that affects organic compound mechanisms accountable for control vital sign, pressure level, appetite, attention, mood and emotional responses associated with alertness [68].

2.5.3 Tramadol

Tramadol hydrochloride (Trhc) is analgesic drug, acting mainly on the central nervous system [69]. It has been mostly used to treat pain, although its use to treat anxiety and depression has also been documented [70]. These properties arise from the fact that they inhibit serotonin responsible for the inhibition of pain transmission in the spinal cord [71].

This drug is structurally related to codeine and morphine, but it is 6000-times less potent than morphine and 10-times less potent than codeine [72, 73, 74]. It appeared in the 1970, but only approved by the Food and Drug Administration (FDA) in 1995 for the management, treatment and relief of moderate to severe pain conditions [75, 76]. Trhc is more advantageous than other, since it exhibits a lower incidence of side effects and abuse potential [77, 78].

The molecular structure of tramadol ($C_{16}H_{25}NO_2$), which contains cyclohexane attached to the meta-substituted phenolic ring, has two stereogenic centers at C_{14} and C_{15} of the cyclohexane ring that result into four possible isomeric configurations (1R,2R,1S,2S) [79]. As show in figure (2.7).

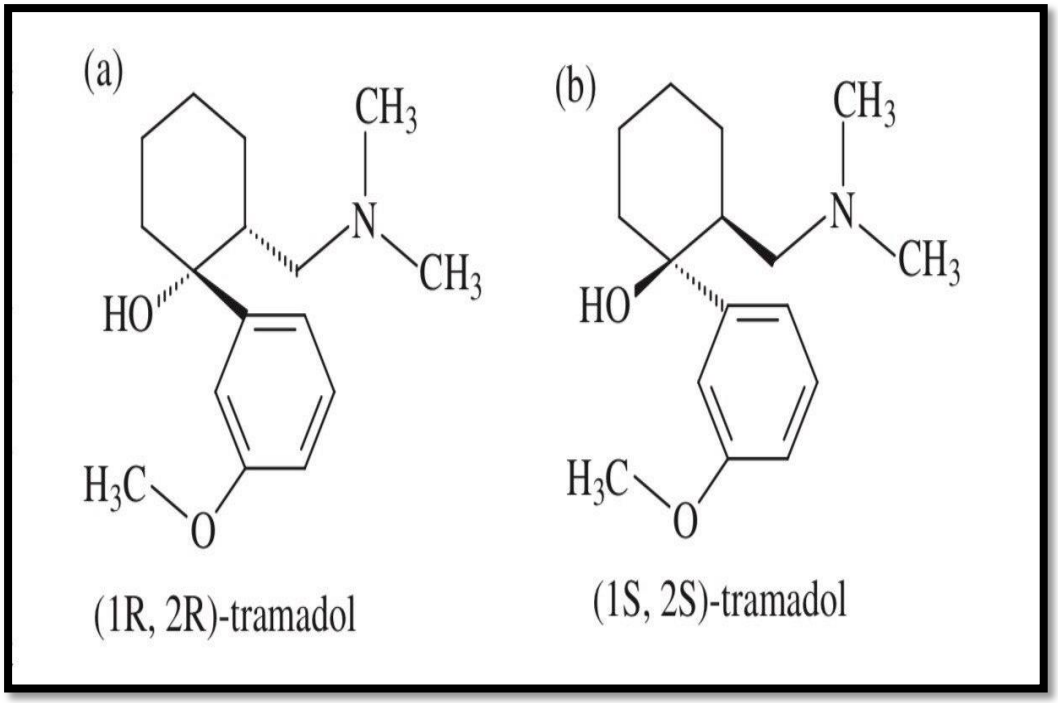


Figure 2.7: Structures of (a) 1R, 2R tramadol and (b) 1S, 2S tramadol [79].

3. Drugs Preparation and Analyzing Methods

In this chapter, samples preparation and analyzing methods will be explained. The abbreviations used are as follows: Methamphetamine, MAMP, Amphetamine, AMP and Tramadol, TR.

3.1 Samples Preparation

The sample of drugs (Amphetamine, Methamphetamine and Tramadol) has been obtained from The General Directorate for Narcotics and Psychotropic Substances Control.

The samples were prepared in two forms (powder and fingerprint samples), the AMP tablets, MAMP solid crystals and tramadol tablet have been crushed using an electric crusher to get a powder of drugs.

In this work the first Raman spectrometer of the Ministry of Science and Technology was used and has the following specifications (manufacturer Bruker, wavelength 532 and 758 nm), and the second is located in Al-Razi lab and has the following specifications (Manufacturer StellarNet, wavelength 532 nm).

As for the GC-MAS device, it is located in the forensic laboratory of the province of Babylon with the specifications (manufacturer name Agilent Technologies, Model 7890A).

3.2 Work Scheme

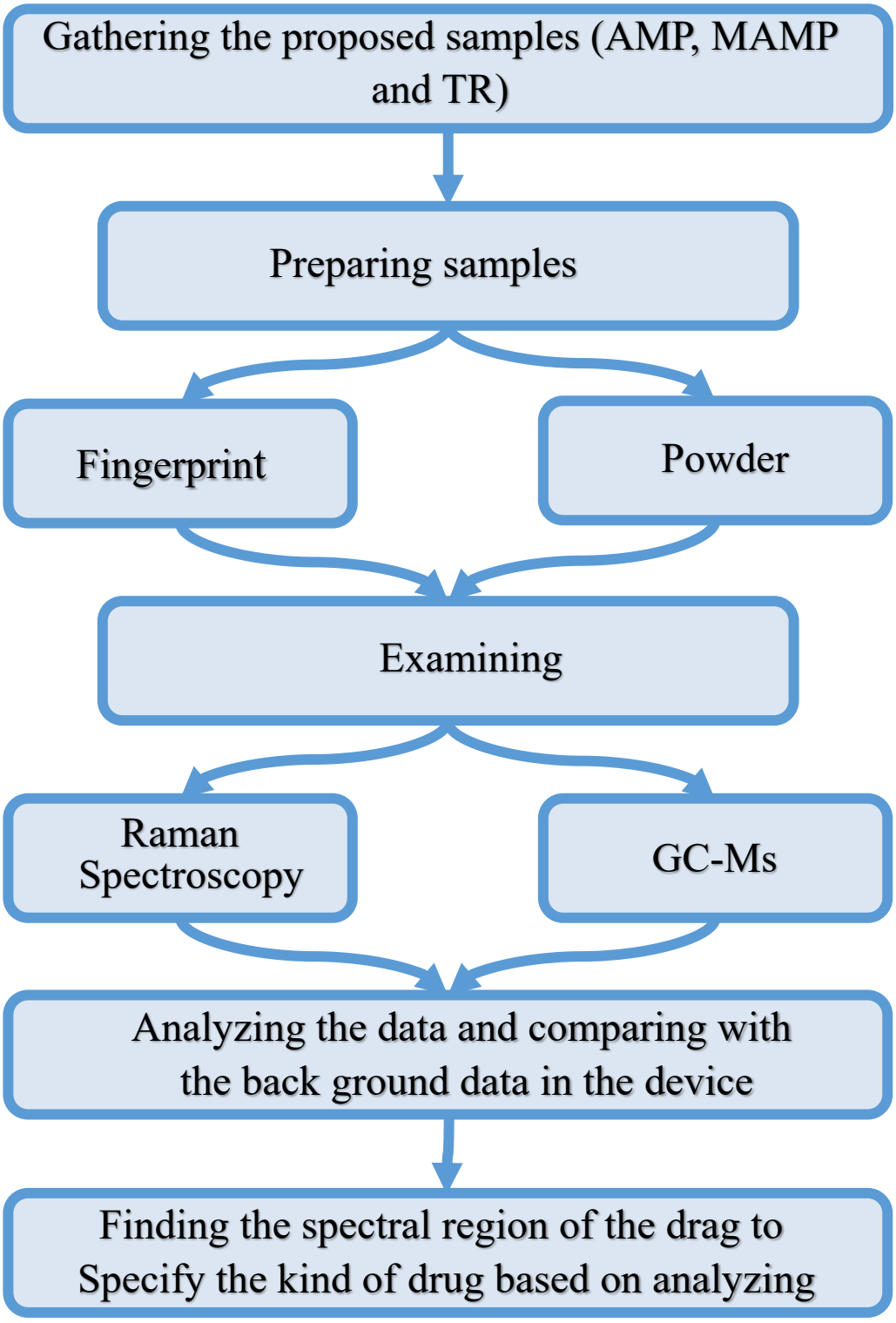


Figure 3.1: The main steps of the work.

3.2.1 Powder Sample Preparations to examining by (GC-MS) device:-

The powder samples of drugs were prepared as follows:

a- A (0.05) gm of each drug was measured separately as shown in Figure 3.2a. Then, each sample has been dissolved in (0.5) ml of methanol.

b- A Vortex rotary device has been used to mix the sample with methanol solution as shown in Figure 3.2b.

c- After that, the solution (drug + methanol) has been diluted with (5) ml of methanol. Finally, a 2 ml of each solution has been injected into a vial to keep and prepare it for analysis and measurements as shown in Figure 3.2c.

3.2.2 Fingerprint Samples Preparation to examining by (GC-MS) device:

Fingerprint samples have been prepared as follows:

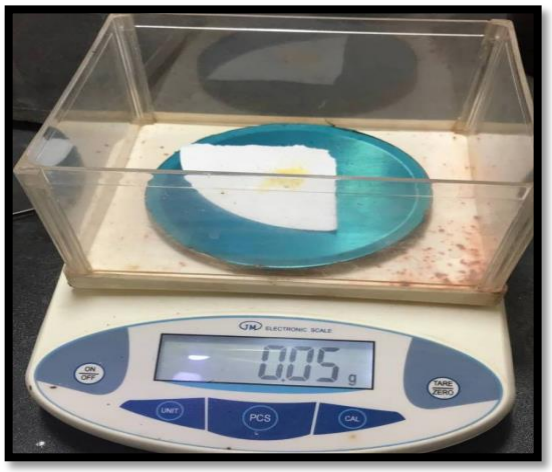
a- A pure fingerprint was printed on a clean glass slide.

b- One finger was smeared with amphetamine powder and another fingers with methamphetamine, tramadol powder.

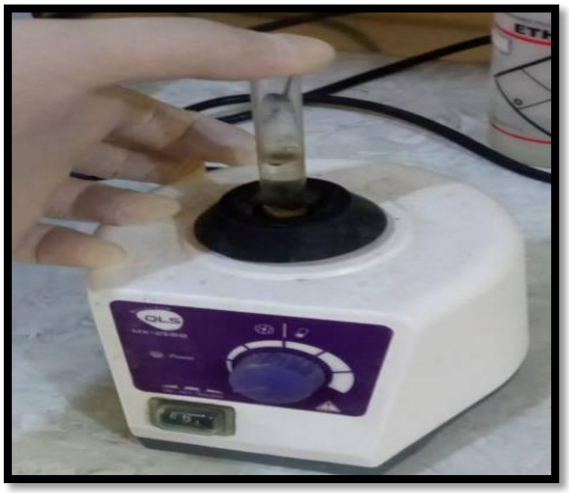
c- The excess of the drug powder was removed from both fingers with a clean brush.

d- Each fingerprint was taken printed on a glass slide (Figure 3.3.a).

e- The place of the fingerprints (contaminated and pure) was erased from the glass slides with a special tool (Figure 3.3.b), then each was placed in (2) ml of methanol (Figure 3.3.c), and (1) ml of each were injected into the GC-MS device.



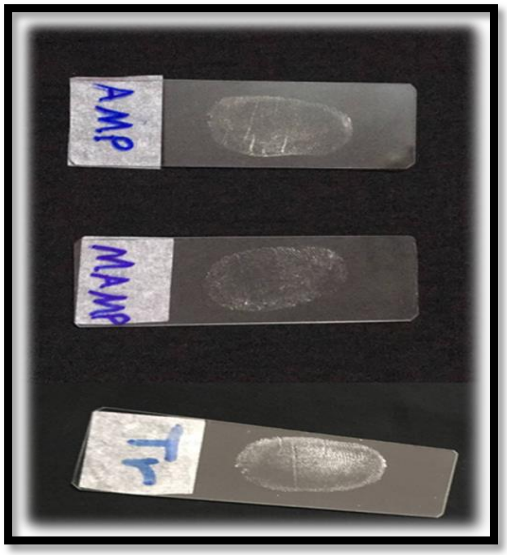
a



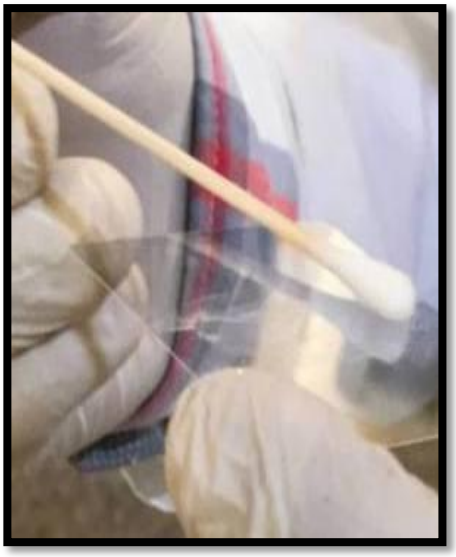
b

c

Figure 3.2: (a) The amount of powder sample on the scale meter, (b) The process of mixing the sample by the rotary Vortex device, (c) The solution samples in the vials.



a



b

c

Figure 3.3: (a) contaminated fingerprints on glass slides, (b) the process of scanning the location of fingerprints from the slides, (c) samples of fingerprints in tubes.

3.2.3 Description of Technique Gas Chromatography–Mass Spectrometry

Drug samples were examined using Gas Chromatography-Mass Spectrometry (GC-MS), where drugs were detected and data obtained by (GC-MS) technology within 20 minutes, it is an excellent technique for detecting vehicles, especially in forensic medicine.

The GC-MS device Figure (3.4) consists of three parts:-

1. Injector.
2. Mass Analyzer.
3. The oven.

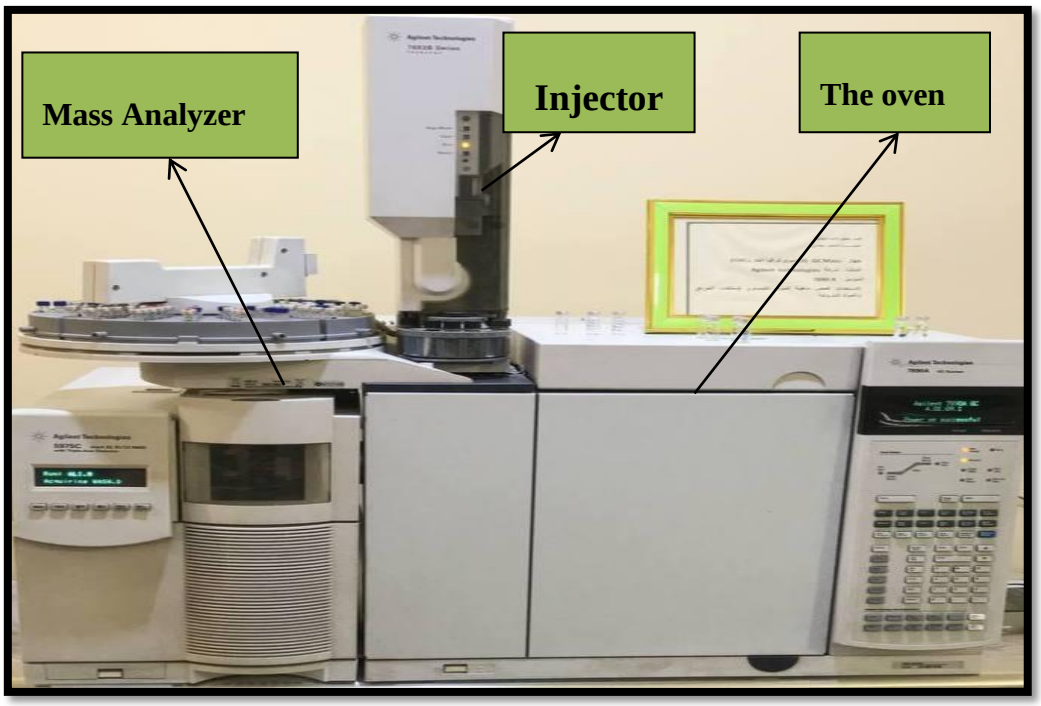


Figure 3.4: The (GC-MS) device.

The method of chemical analysis using gas chromatography (GC) and mass spectrometry (MS) is one of the most important, effective and distinguished methods as it gives accurate results.

Gas chromatography separates compounds into complex mixtures, while mass spectrometry determines the molecular weight of individual components, aiding in compound identification. Since it is a specific test, GC-MS is a great technique for professionals to identify the substances in a sample.

A specific test determines the presence of a particular drug in a sample in a positive way. The GC analytical process produces a representative chromatographic result. The sample is injected into the injection port of the GC instrument by the analyzer. The injected sample is evaporated, and the individual components are separated by GC. Each component in the sample produces a distinct peak that is recorded electronically. The time interval, which is the elapsed and recorded time between sample injection and the washing procedure, is measured by GC (separation of one substance from another). The time interval helps scientists distinguish certain substances, and the peaks recorded are often proportional to the amount of material in the sample examined [80].

3.2.4 Powder Sample Preparations to examining by Raman Spectroscopy

The next step is Preparation samples powder of substance (amphetamine, methamphetamine and tramadol) to be examined by Raman spectroscopy.

The powder samples of drugs were prepared as follows:

a- Approximately (0.02) gm of powder of each substance were taken separately on clean glass slides as shown in Figure (3.5).

b- Examined these slides under a Raman Microscope.

Figure 3.5: Drugs powder samples on glass slides.

3.2.5 Fingerprint Samples Preparation to examining by Raman Spectroscopy

Fingerprint samples have been prepared as follows:

a- One finger was smeared with methamphetamine powder and another fingers with amphetamine and tramadol powder

b- The excess of the drug powder was removed from both fingers with a clean brush.

c- The contaminated fingerprints were taken on clean glass slides (Figure 3.6).

d- Examined these slides under a Raman Microscope.

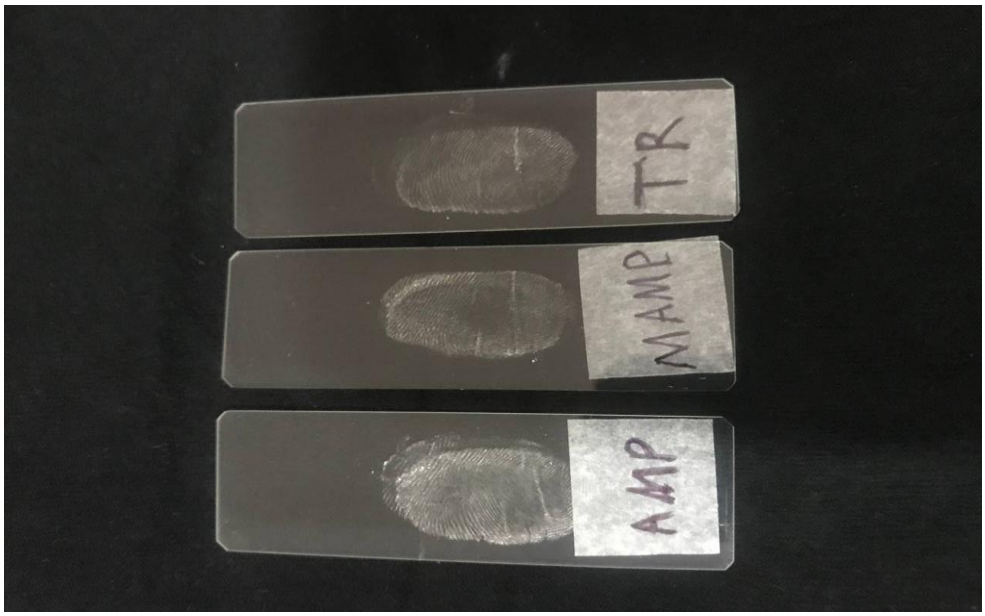


Figure 3.6: Drugs fingerprint samples on glass slides.

3.2.6 Description of the Raman spectroscopy

In this work, the results of material screening (AMP and MAMP) were obtained with a Raman spectrometer located in the Nano-lab of the Ministry of Science and Technology (Figure 3.7). Drug samples were examined using a Raman spectrometer, were determined within 3 min or less. This analysis is very legitimate allowing the sample to be analyzed without damaging it. The slides containing the samples are placed under the microscope lens and the laser is focused on the sample's scattering surface. The registration process begins immediately. Within at least 3 min, the Raman spectra are repeatedly recorded, meanwhile, the axis of the laser beam probe is under optical observation and permanently tuned

to match the top of the amplified scattering. For further evaluation, the three-point material spectra were obtained.

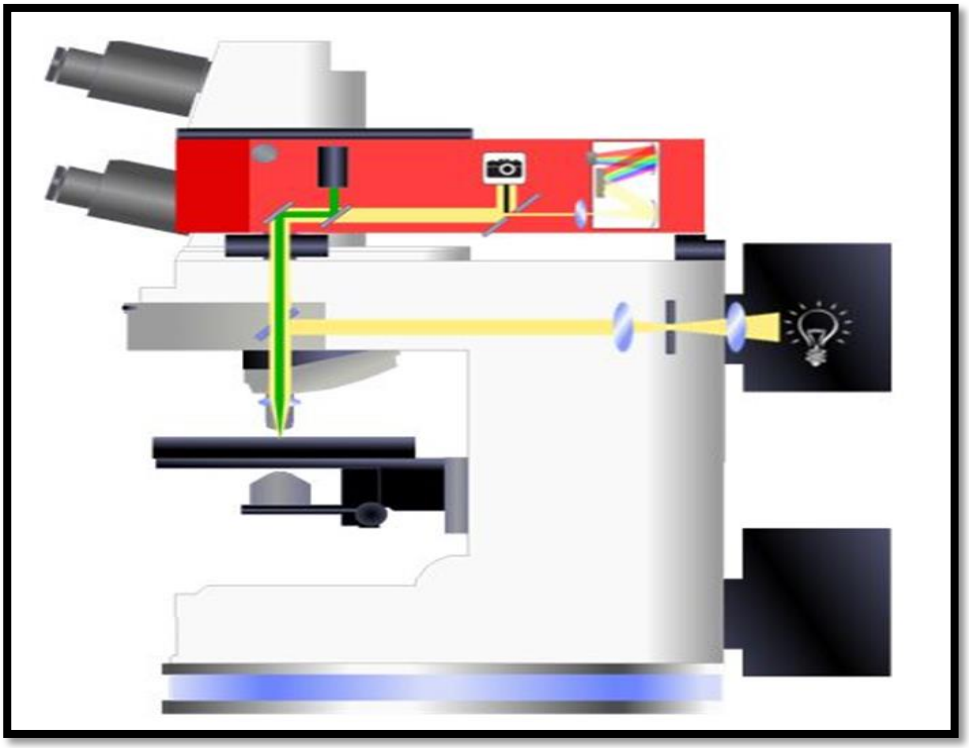


Figure 3.7: Image of the Raman spectrometer in the Nano Laboratory of the Ministry of Science and Technology.

But the results of screening (TR) were obtained with a Raman spectrometer located in Al-Razi lab (Figure 3.8)

Figure 3.8: Image of Raman spectrometer located in Al-Razi lab.

4. Introduction

In this chapter, the results and discussion will be presented as follows:

4.1 AMP Analysis Using (GC-MS) Device

Analysis using Gas Chromatography (GC) and Mass Spectrometry (MS) is an effective method. This technique gives us very accurate results and data in determining the type of compounds to be detected.

The recording results have been obtained from the computer connected as printed paper form so that the results cannot manipulate. Where we processed it by (Get data and Orgion) programs.

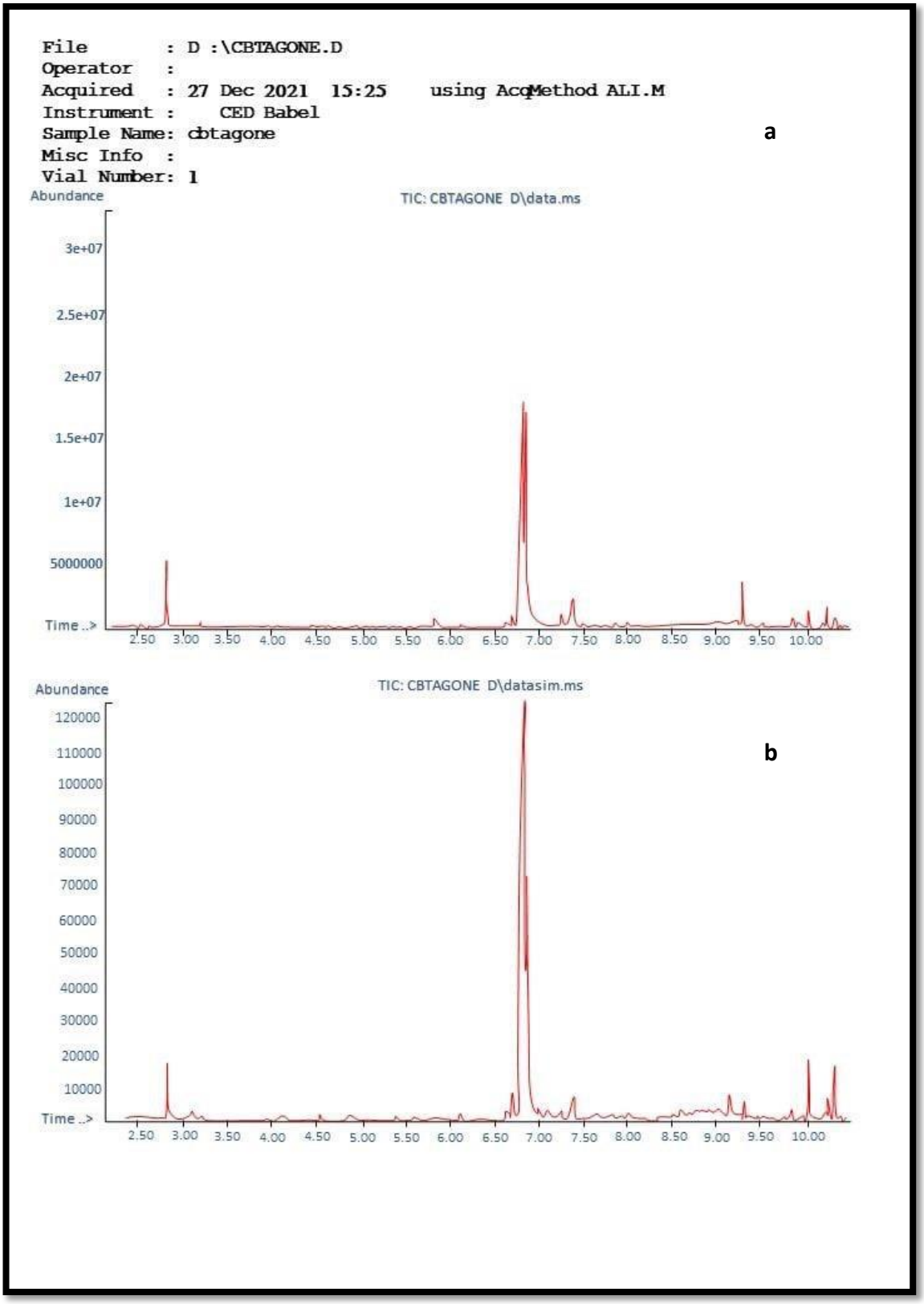


Figure 4.1(a) Real AMP powder sample stored in the device,(b) Examined sample of the same substance.

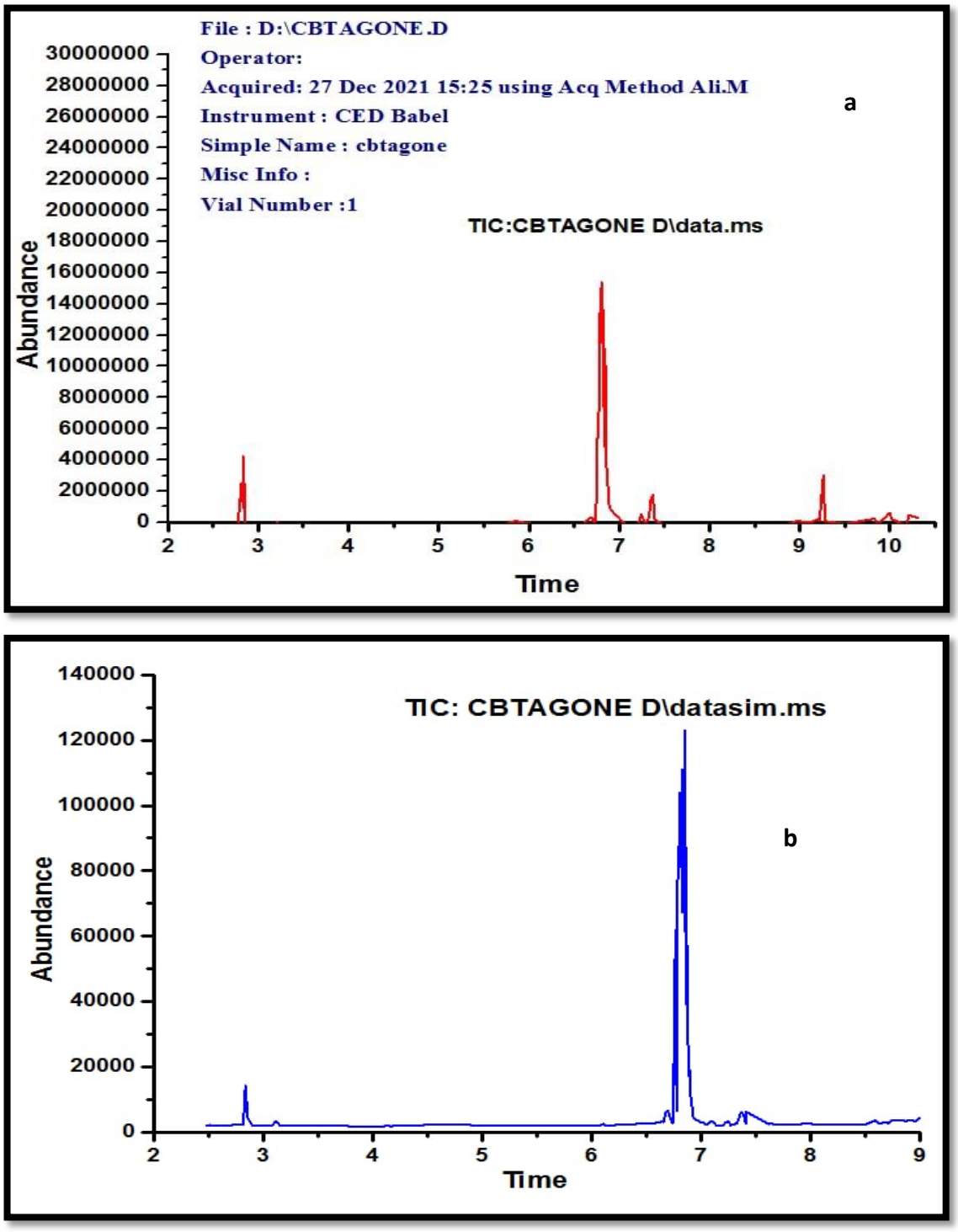


Figure 4.1: (a) Real AMP powder sample stored in the device, (b) Examined sample of the same substance (after processing).

Figure (4.1 a, b) show the real AMP powder sample spectrum stored in the device library, and the sample data of the same examined substance by the (GC-MS) device, respectively. A clear match between the two charts, the highest peak of both charts appears at time 6.8 (min) the data shows that the percentage of congruence is 83%. Also, the obtained data have showed that the examined substance is amphetamine (or so-called cbtagone) with the molecular formula ($C_9H_{13}N$) and molecular weight (135.10 gm) as presented in Table (4.1).

Table 4.1: The data of AMP powder.

Name	**Amphetamine**
Molecular Formula	$C_9H_{13}N$
Match Quality	83
Molecular Weight	135.10 gm

On the other hand, Figure (4.2 a, b) shows the contaminated fingerprint amphetamine sample real spectrum stored in the device library, and the sample data of the same examined fingerprint by the (GC-MS) device, respectively.

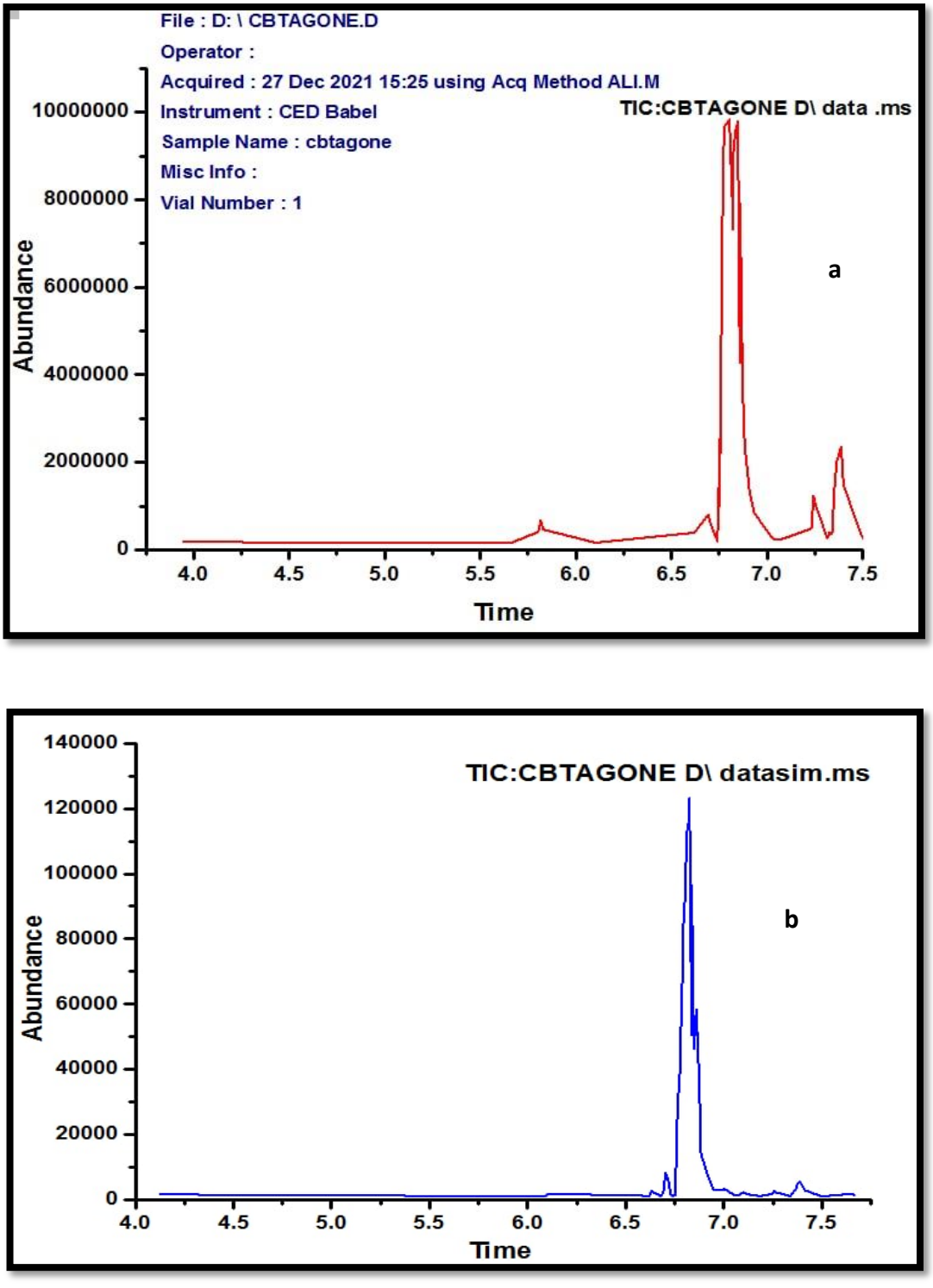


Figure 4.2: (a) Real AMP fingerprint sample stored in the device,

(b) Examined sample of the same fingerprint (after processing).

A clear match between the two charts, the highest peak of both charts appears at time 6.8 (min). The data shows that the percentage of congruence is 83%. Also, the obtained data have showed that the examined fingerprint contain amphetamine substance as shown in Table (4.2).

This means that the (GC-MS) device can sense a small amount of materials, such as those that are between the skin lines in the fingerprint.

Table 4.2: The data of AMP fingerprint.

Name	**Amphetamine**
Molecular Formula	$C_9H_{13}N$
Match Quality	83
Molecular Weight	135.10 gm

Table 4.3: The readings of the AMP samples that were examined by the (GC-MS) device.

shape of sample	**Time (min)**	**Abundance**
Powder	6.854	130000
Fingerprint	6.821	130000

The above table indicates that the obtained data are identical for both forms of sample, and this indicates the accuracy of the gas chromatography technique associated with mass spectrometry.

Figure (4.3 a, b) shows the real pure fingerprint sample spectrum stored in the device library, and data of the same fingerprint sample examined by the (GC-MS) device, respectively.

Where found that there is a clear difference between the graph of the fingerprint contaminated with the drug powder and the pure fingerprint, but found a clear match between the graphs as well as the data for the contaminated fingerprint and powder samples.

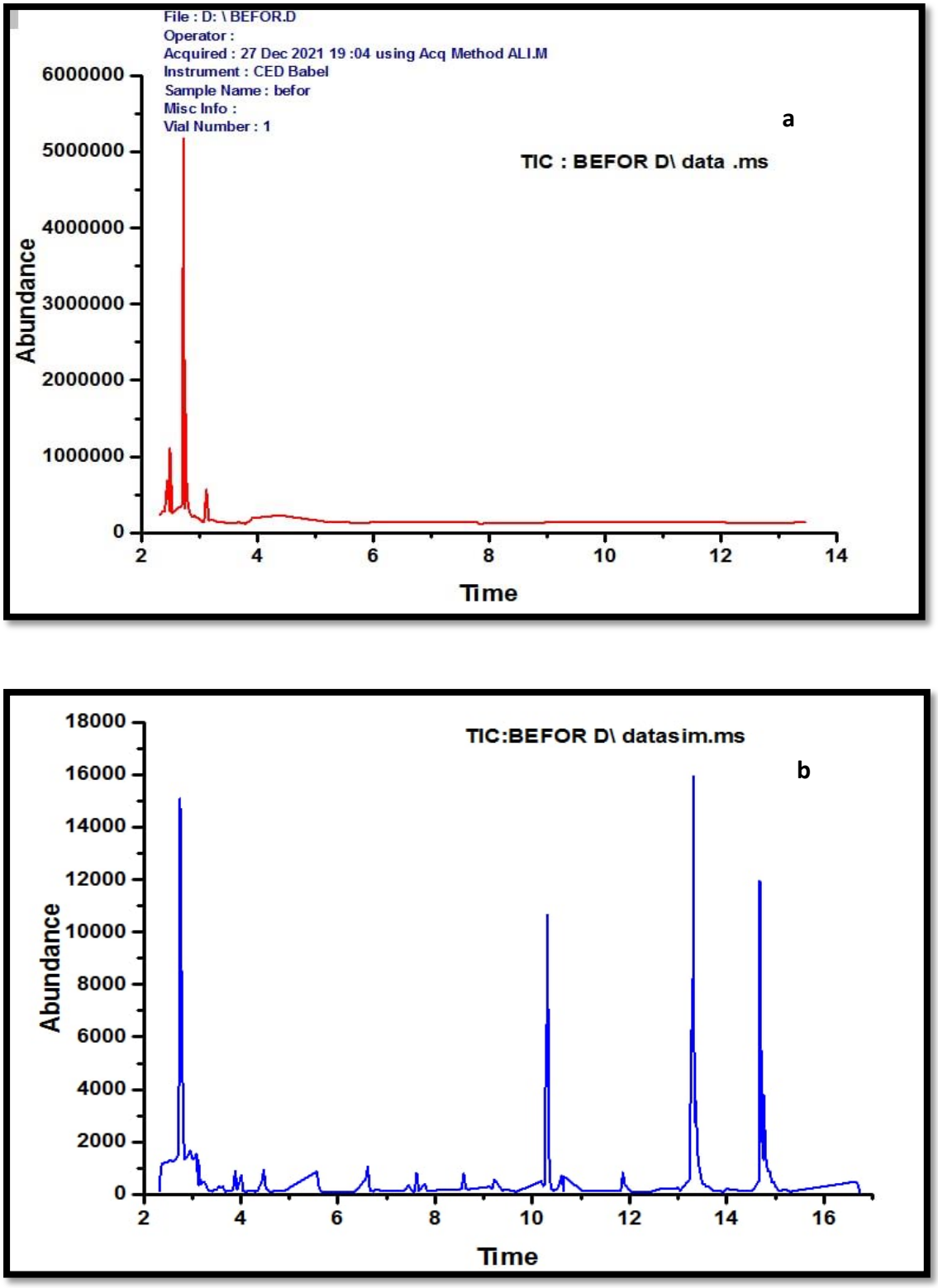


Figure 4.3: (a) Real pure fingerprint sample stored in the device, (b) Examined sample of the same fingerprint (after processing).

4.2 AMP Analysis Using Raman Spectroscopy

The samples were examined using Raman spectrometer. The spectra were obtained in an average of one minute. We were given a disk containing Raman spectra images of the examined samples as well as images of the shape of the samples under a Raman microscope.

The Raman spectrum of a sample of amphetamine powder is shown in Figure (4.4), where we notice the appearance of Raman shift in range (1000- 3100) cm^{-1}, for the three readings represented by blue, red and pink colors.

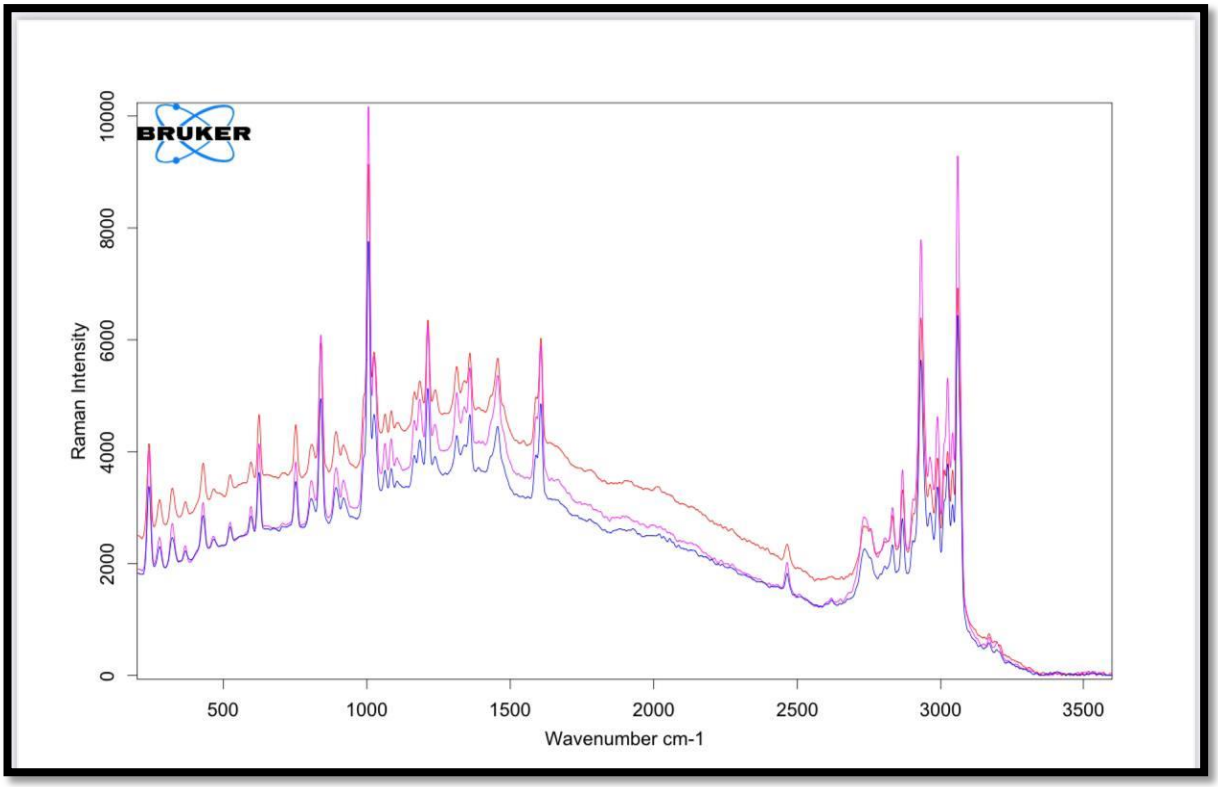


Figure 4.4: The Raman spectrum of AMP powder sample.

An image of amphetamine powder under a Raman microscope is shown in Figure (4.5), where the colored points represent the different position of areas which examined to obtain accurate results.

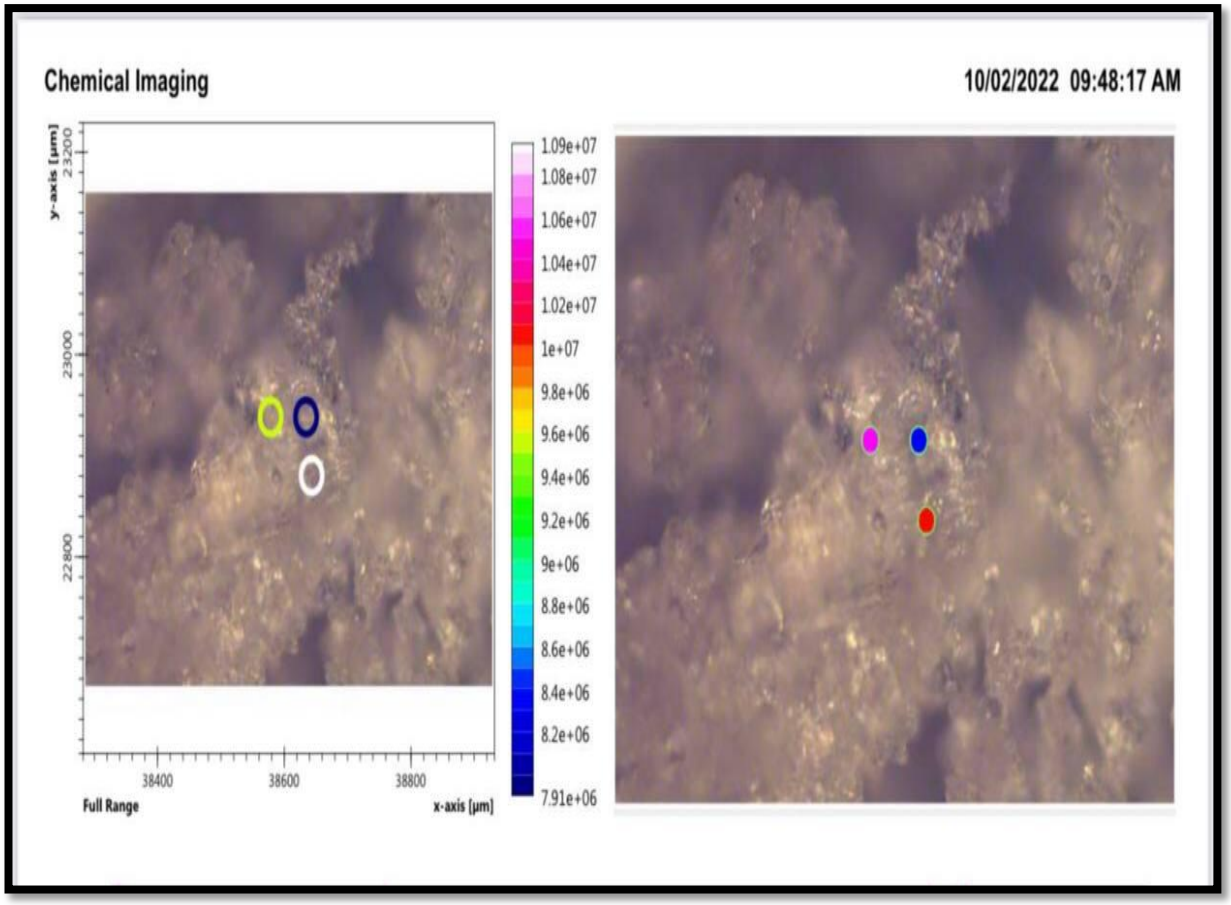


Figure 4.5: AMP powder under a Raman microscopy.

On the other hand, the Raman spectrum of a fingerprint sample contaminated with the powder of the same substance appears in Figure (4.6), where Raman shift of this spectrum appeared in the range (500-1500) cm^{-1} also for the three readings.

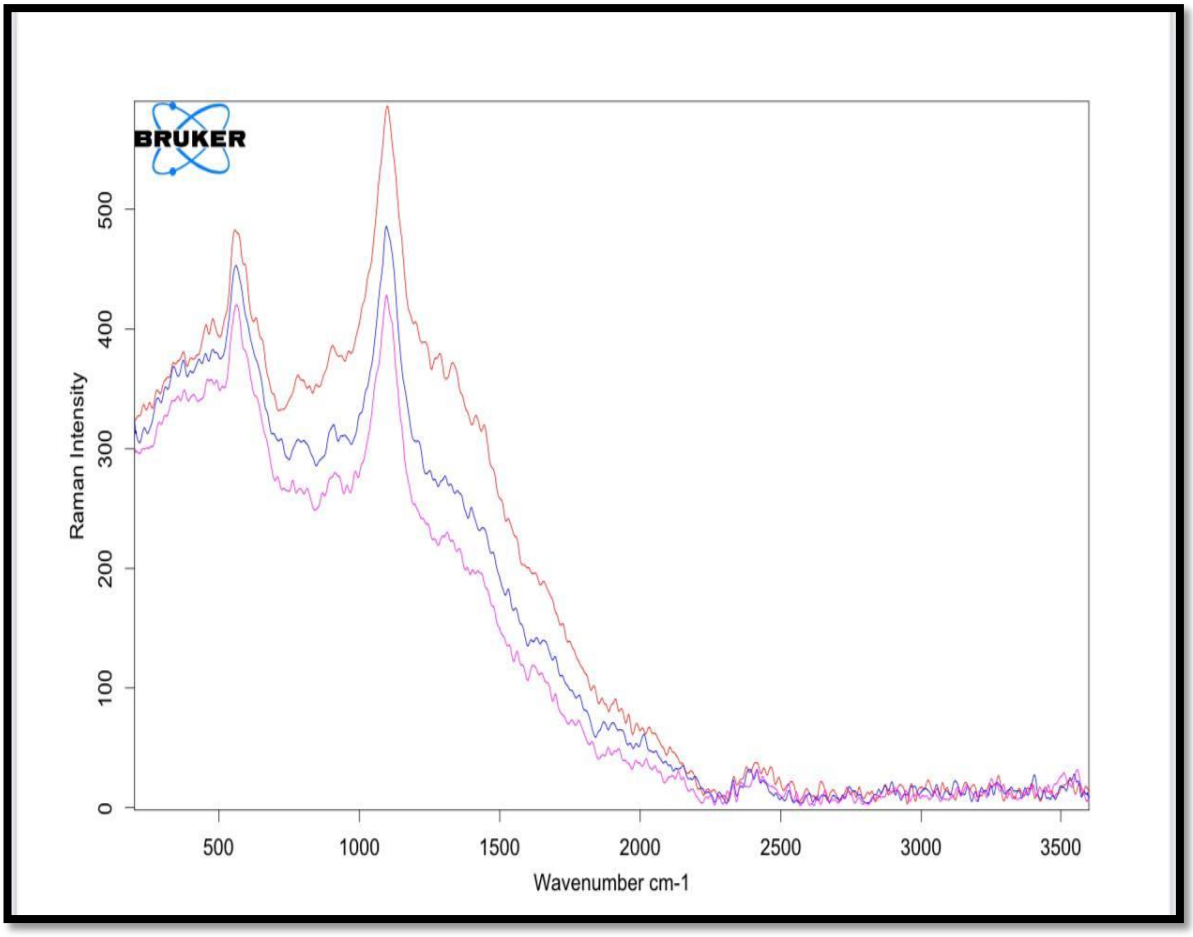


Figure 4.6: The Raman spectrum of a fingerprint sample contaminated with AMP powder.

The image of a fingerprint sample contaminated with amphetamine powder by Raman microscope is shown in Figure (4.7) where the colored points represent the different position of areas which examined to obtain accurate results.

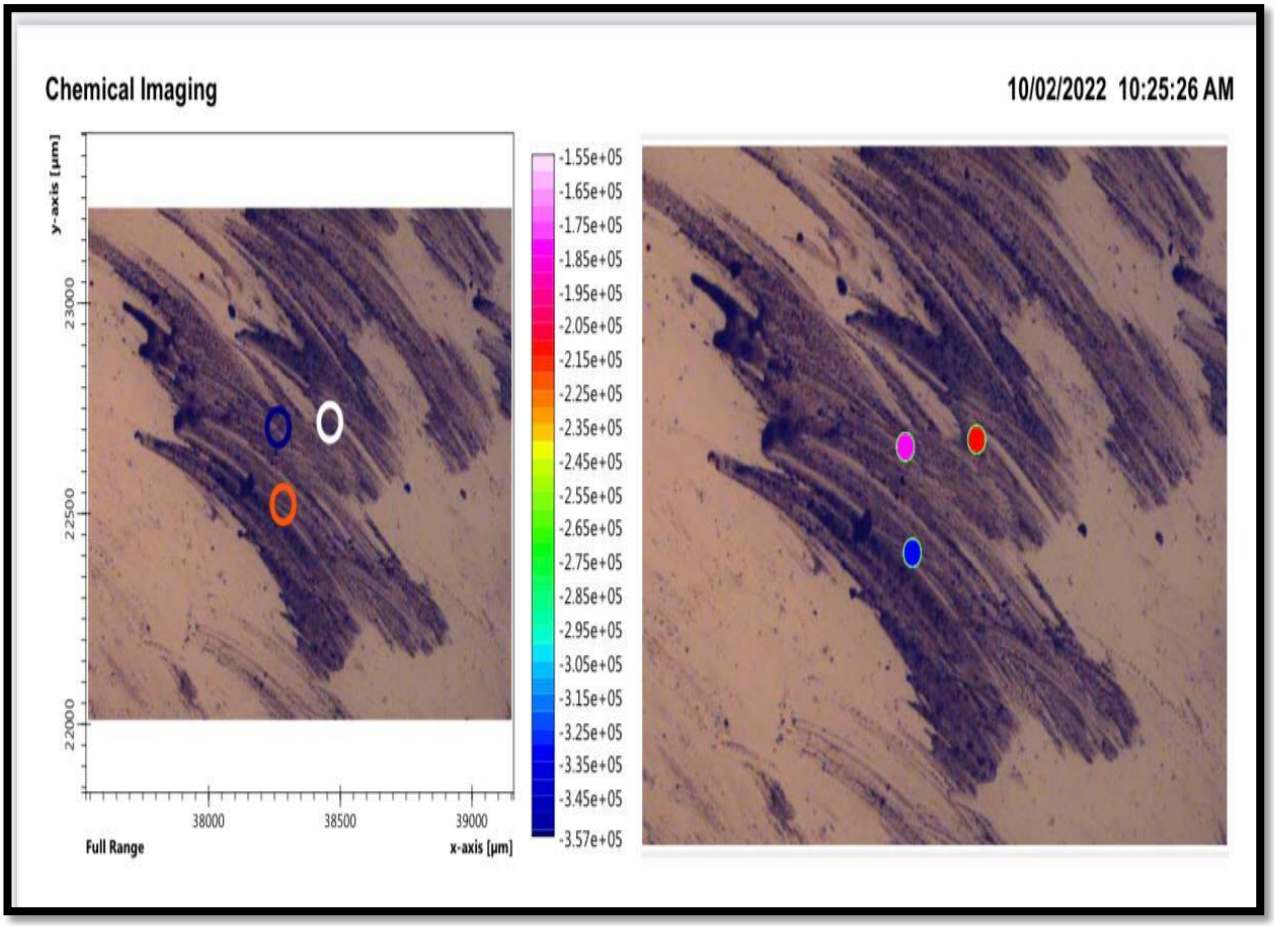


Figure 4.7: A fingerprint sample contaminated with AMP powder under a Raman microscopy.

The blue, red and pink spectra (in the previous figures) show three successive readings of the spectrum from the same sample, we found that the three readings for each sample are the same, and this is due to the accuracy of the Raman spectrometer in the measurements, where one reading was enough to know the results, but three readings were taken to be accurate reading.

4.3 MAMP Analysis Using (GC-MS) device

The methamphetamine samples were also examined using the (GC-MS) technology, as it gives accurate and effective results. It is used in criminal cases, as well as in the field of forensic medicine to detect crimes and criminals by analyzing the traces of crime as well as the fingerprints of suspects.

Figure (4.8 a, b) shows the real MAMP powder sample spectrum stored in the device library, and the sample data of the same examined substance by the (GC-MS) device, respectively. A clear match between the two charts, the highest peak of both charts appears at time 7.55(min), the data says that the percentage of congruence is 64%.

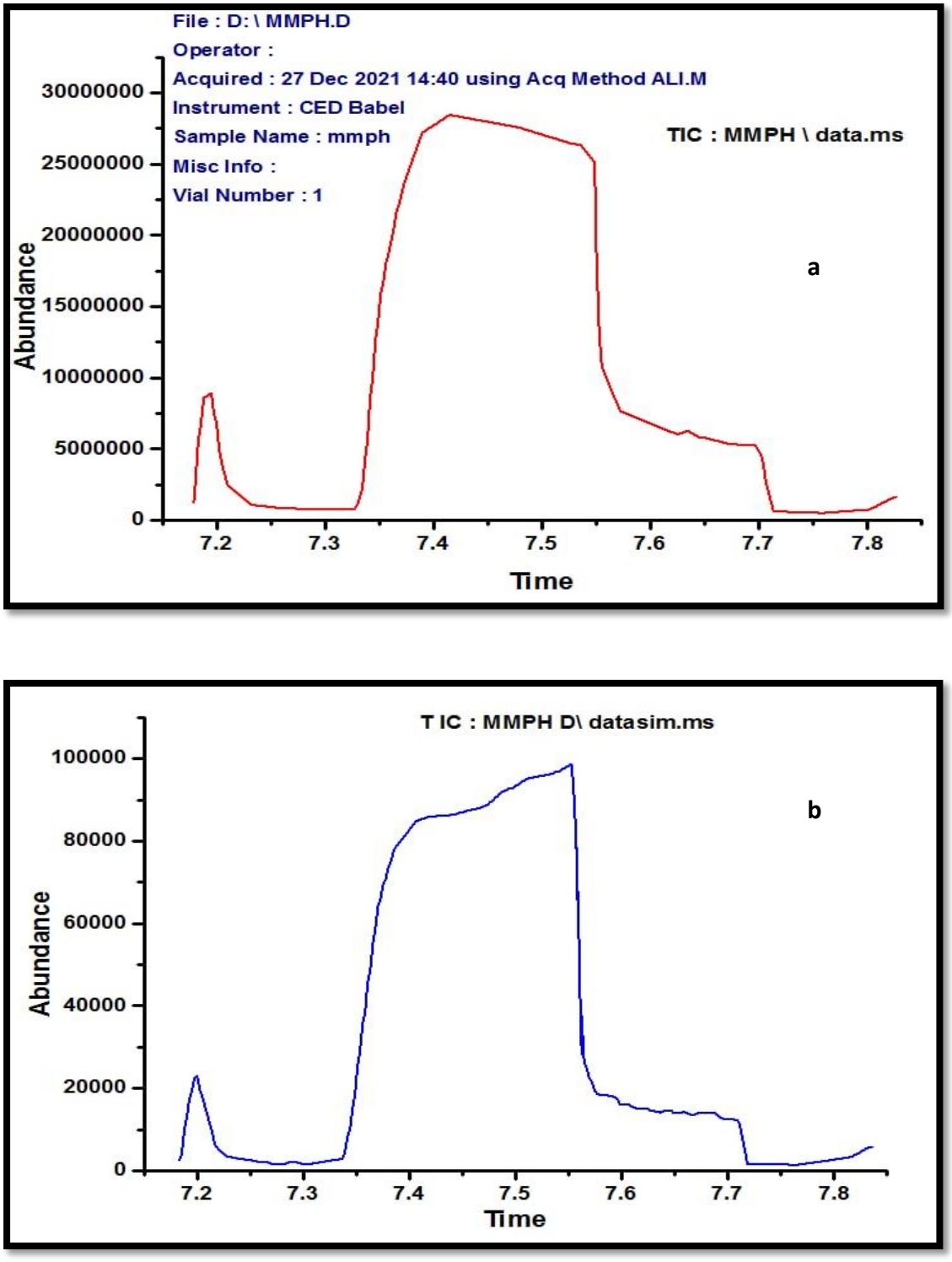


Figure 4.8 :(a) Real MAMP powder sample stored in the device, (b) Examined sample of the same substance (after processing).

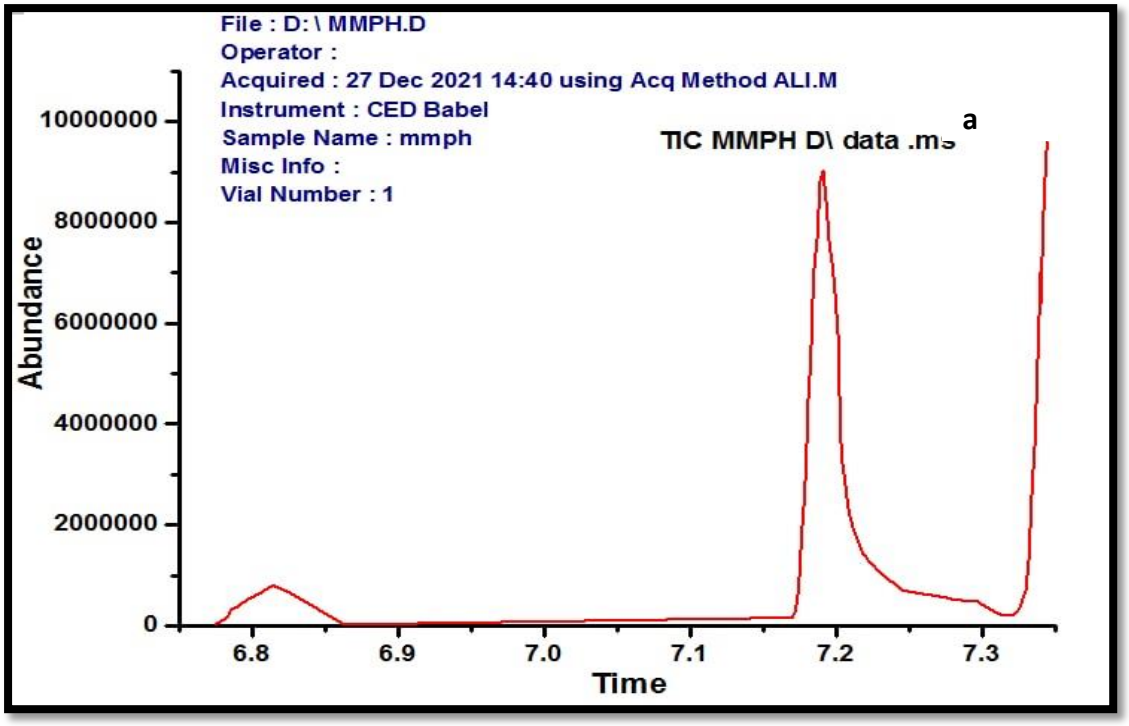
Also, the obtained data have showed that the examined substance is methamphetamine (or so-called crystal) with the molecular formula ($C_{10}H_{15}N$) and molecular weight (149.12 g) as presented in Table 4.4.

Table 4.4: The data of MAMP powder.

Name	**Methamphetamine**
Molecular Formula	$C_{10}H_{15}N$
Match Quality	64
Molecular Weight	149.12 gm

On the other hand, Figure (4.9 a, b) show the contaminated fingerprint methamphetamine sample real spectrum stored in the device library, and the sample data of the same examined fingerprint by the (GC-MS) device, respectively.

A clear match between the two charts, the highest peak of both charts appears at time 7.20 (min), the data shows that the percentage of congruence is 78%. Also, the obtained data have showed that the examined fingerprint contain methamphetamine substance Table (4.5).



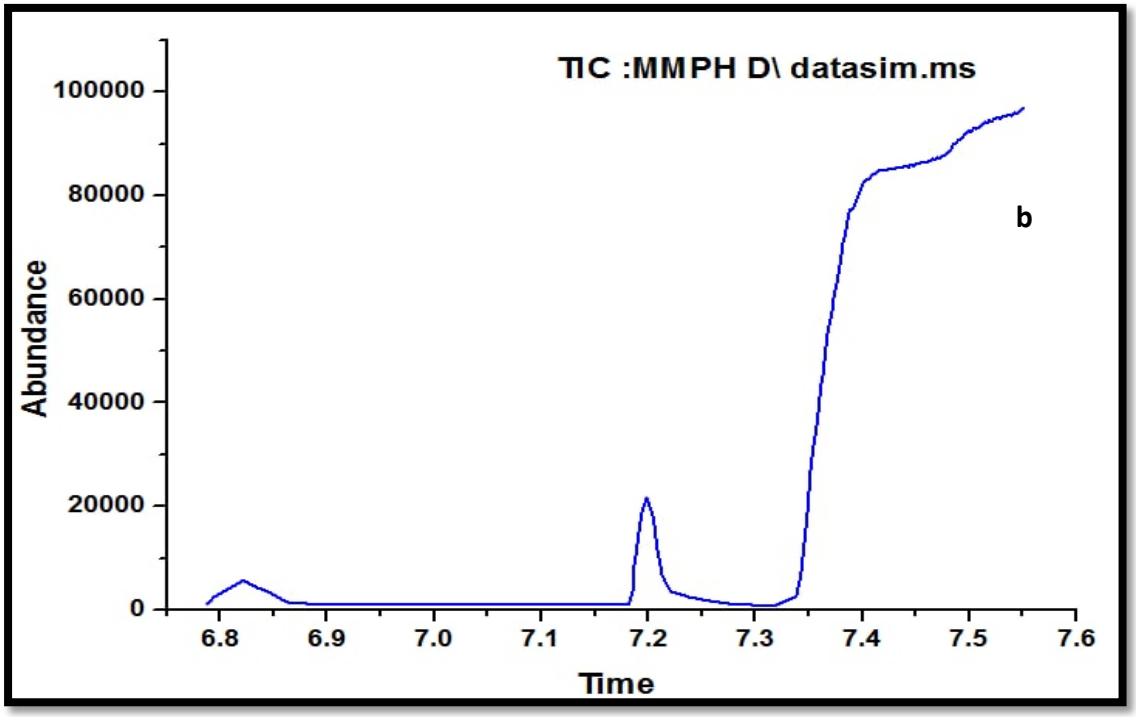


Figure 4.9: (a) Real MAMP fingerprint sample stored in the device, (b) Examined sample of the same fingerprint (after processing).

Table 4.5: The data of MAMP fingerprint.

Name	**Methamphetamine**
Molecular Formula	$C_{10}H_{15}N$
Match Quality	78
Molecular Weight	149.12 gm

Where found that there was a clear difference between the graph of the fingerprint contaminated with drug powder and the pure fingerprint, but found a clear match between the graphs as well as the data for the contaminated fingerprint and the powder sample.

Table 4.6: The readings of the MAMP samples that were examined by the (GC-MS) device.

shape of sample	**Time (min)**	**Abundance**
Powder	7.55	100000
Fingerprint	7.20	20000

The above table indicates that the obtained data are almost identical for both forms of samples, and this indicates the accuracy of the gas chromatography technique associated with mass spectrometry.

4.4 MAMP Analysis Using Raman Spectroscopy

In this work we also examined methamphetamine samples by Raman spectroscopy. Where the Raman spectrum of a sample of methamphetamine powder was as shown in Figure (4.10), where we notice the appearance of the Raman shift at range (500-3500) cm^{-1}, which

is the same for the three readings represented by the colors blue, red and pink.

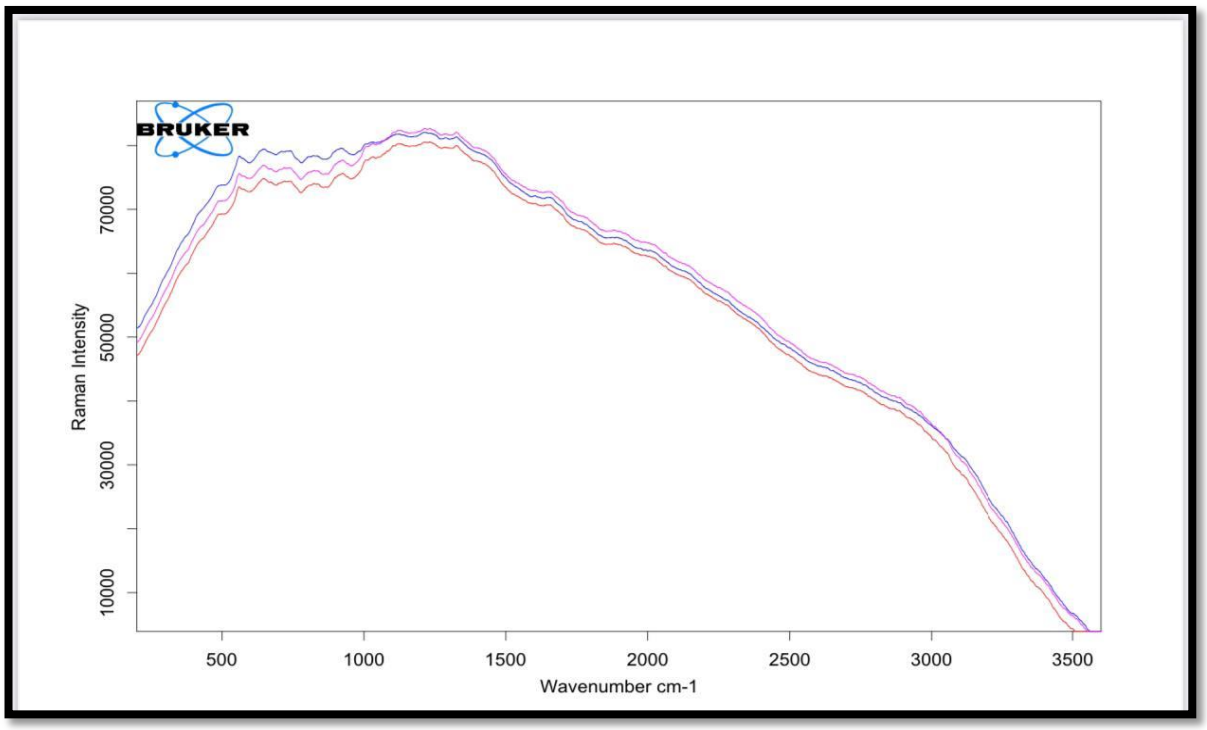


Figure 4.10: The Raman spectrum of MAMP powder sample.

As for the image of methamphetamine powder under a Raman microscope, it is shown in Figure (4.11), where the colored points represent the different position of areas which examined to obtain accurate results.

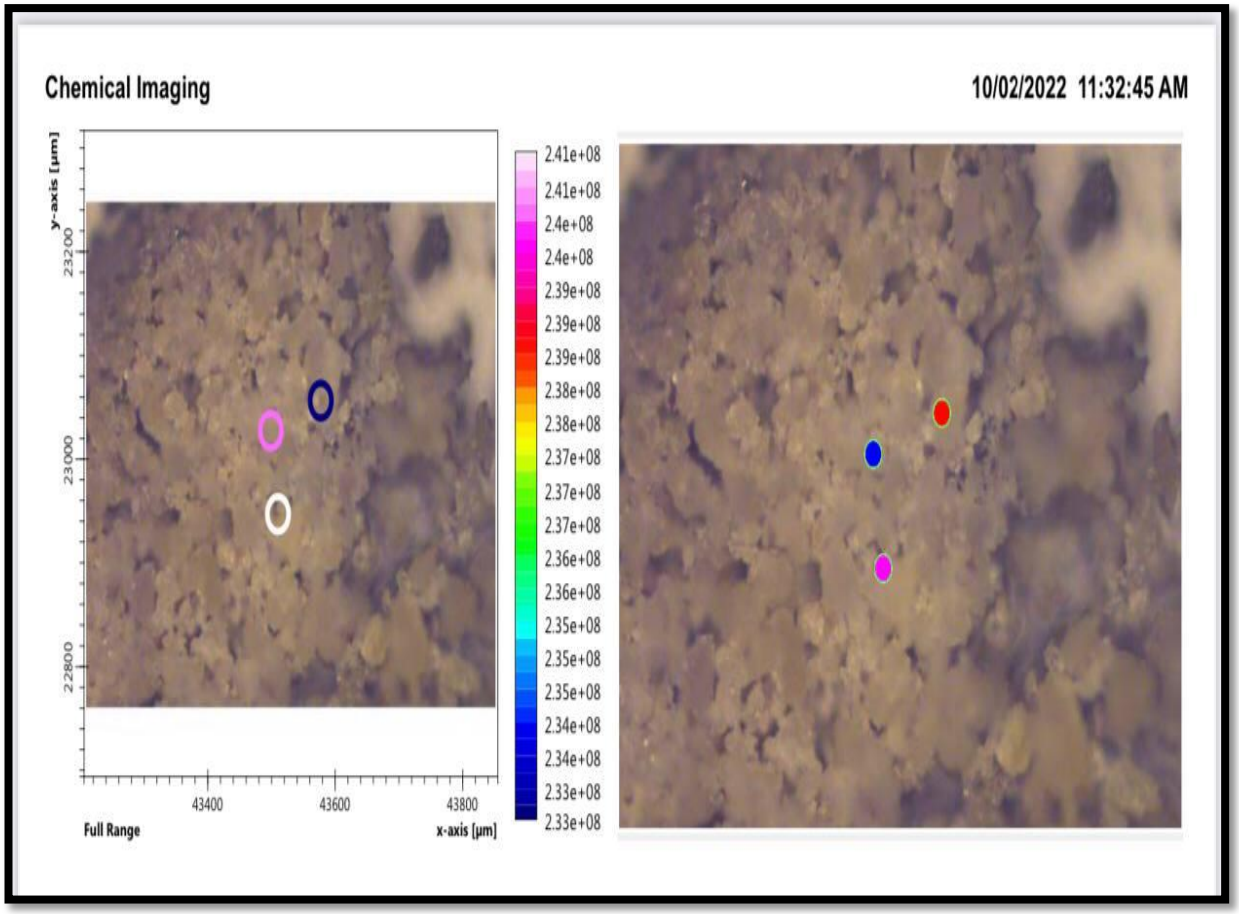


Figure 4.11: MAMP powder under a Raman microscopy.

On the other hand, the Raman spectrum of a fingerprint sample contaminated with the powder of the same substance appears in Figure (4.12), where the Raman shift of this spectrum appeared in the region (1000-3200) cm^{-1} also for the three readings.

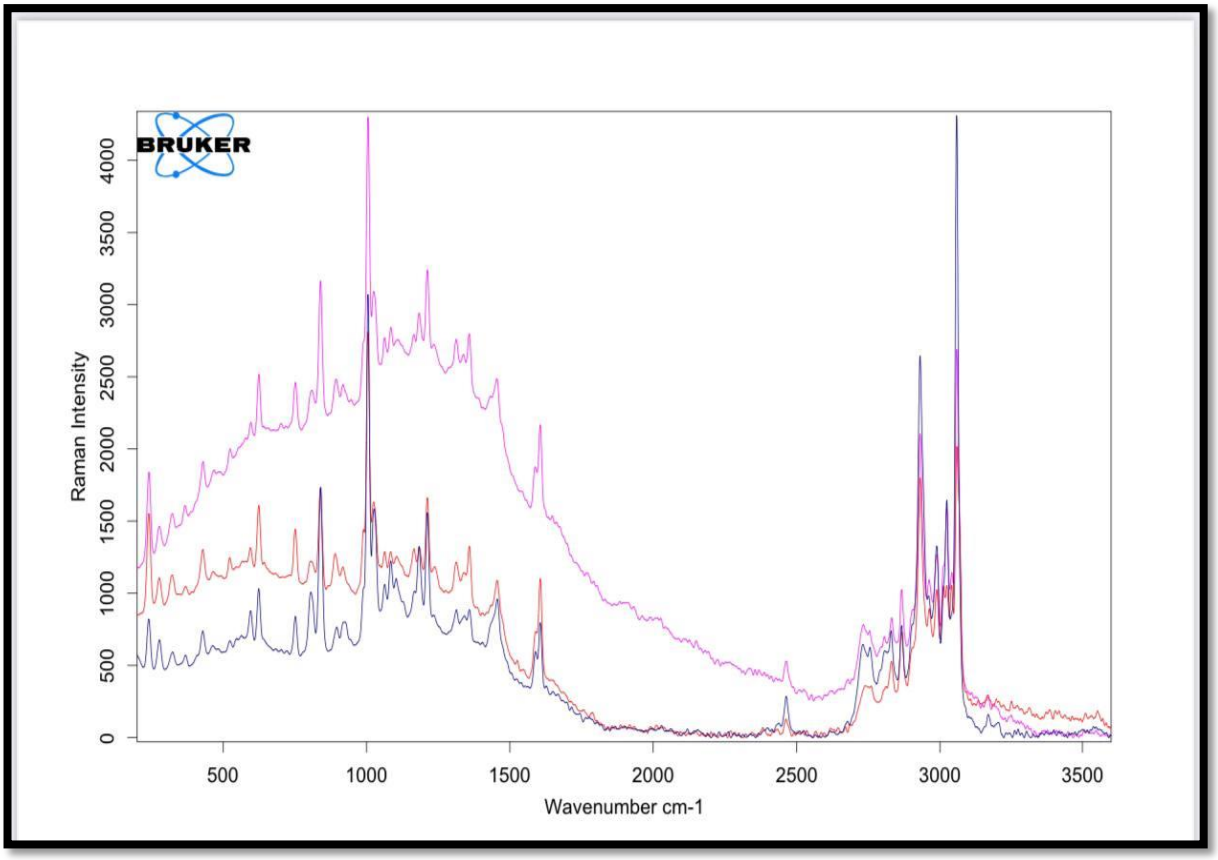


Figure 4.12: The Raman spectrum of a fingerprint sample contaminated with MAMP powder.

The sample image of this contaminated fingerprint by Raman microscope is shown in Figure (4.13), where the colored dots represent the different position of areas which examined to obtain accurate results.

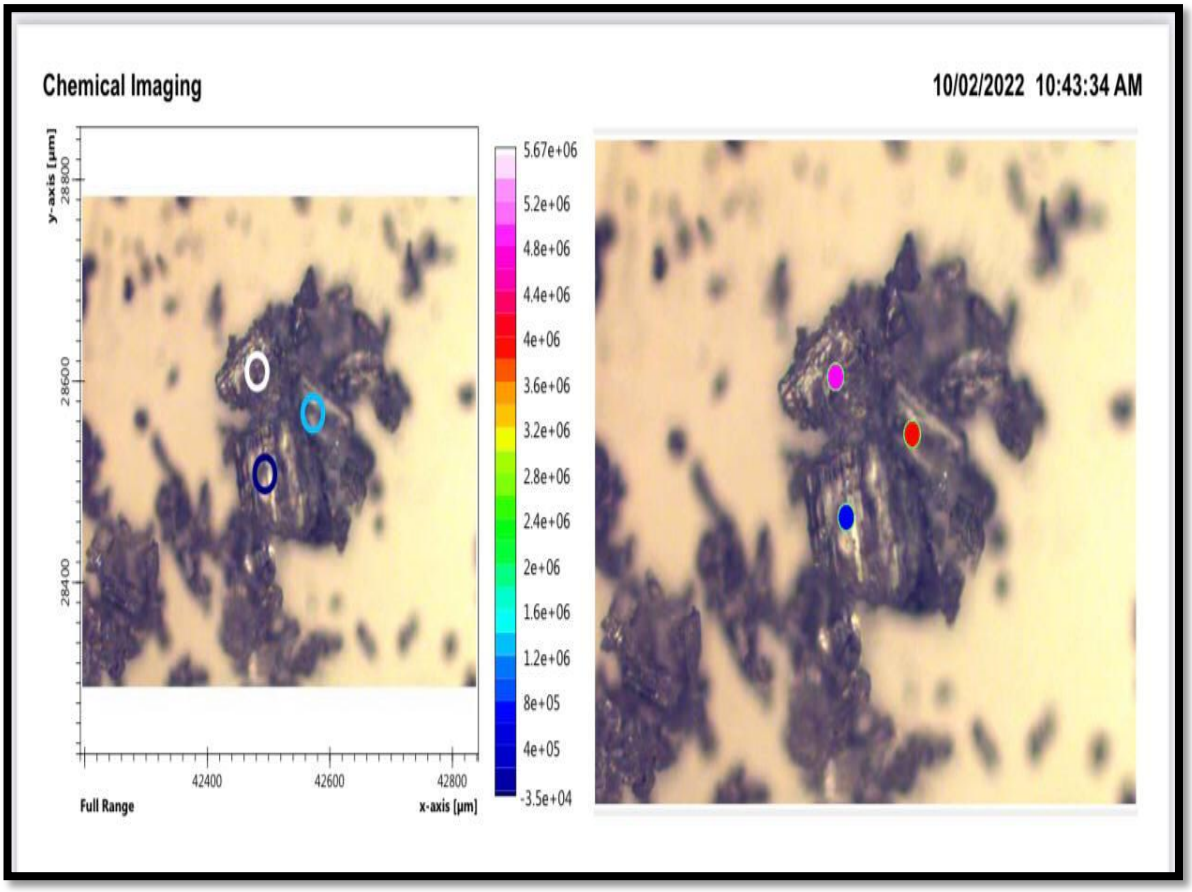


Figure 4.13: A fingerprint sample contaminated with AMP powder under a Raman microscopy.

4.5 TR Analysis Using (GC-MS) device:

The last substance examined using GC-MS technology is tramadol. Figure (4.14 a,b) shows the spectrum of the true TR powder sample stored in the device library, and the sample data for the same material examined by the device (GC-MS), respectively. A clear match between the two charts, i.e. the highest peak of both charts appears at time 13.8 (min), and the data shows that the percentage of congruence is 72%.

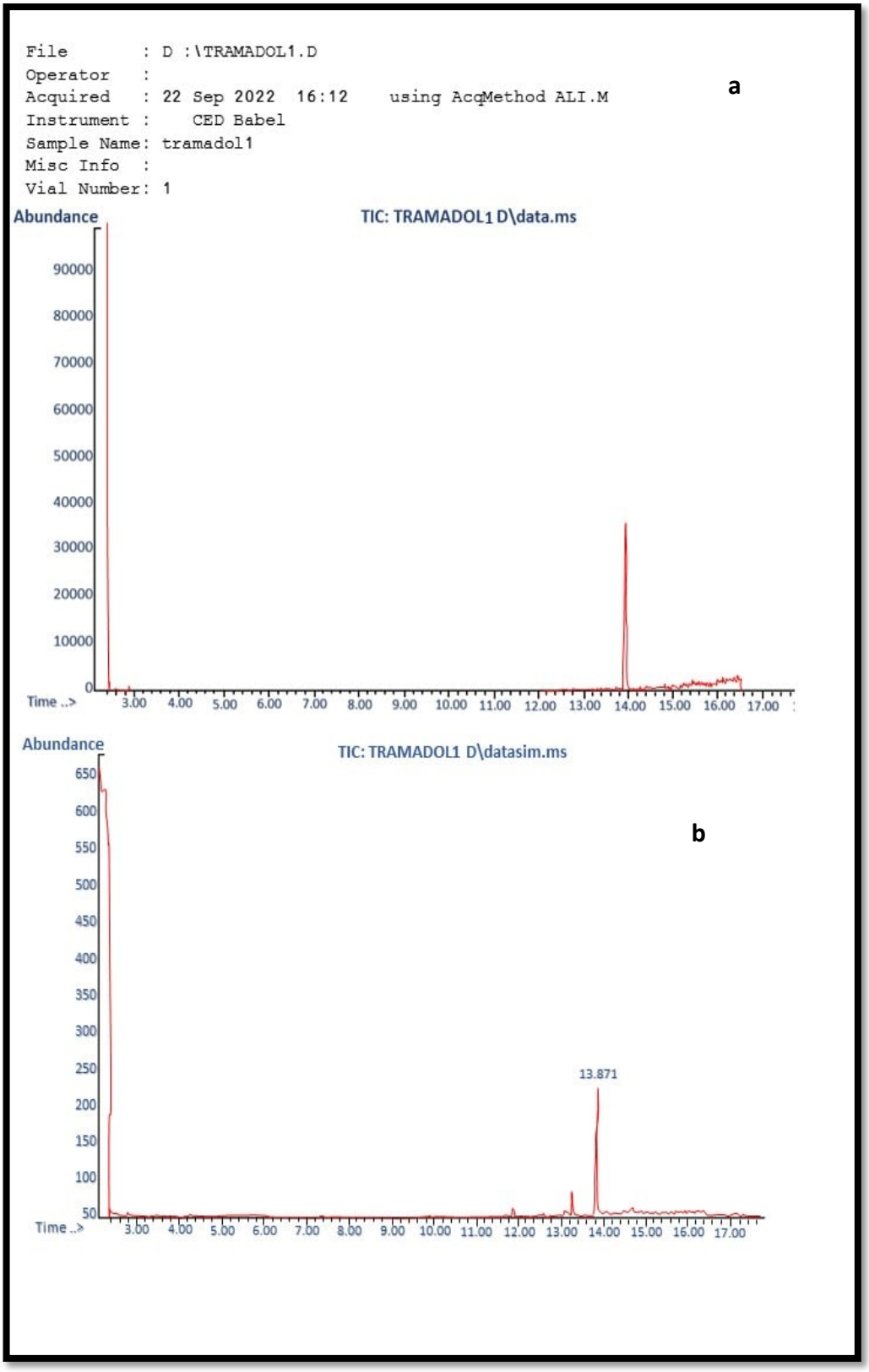


Figure 4.14: (a) Real TR powder sample stored in the device,

(b) Examined sample of the same substance.

Also, the obtained data have showed that the examined substance is tramadol with the molecular formula ($C_{16}H_{25}No_2$) and molecular weight (263.19 g) as presented in Table (4.7).

Table 4.7: The data of TR powder.

Name	**Tramadol**
Molecular Formula	$C_{16}H_{25}N0_2$
Match Quality	72
Molecular Weight	263.19 gm

On the other hand, Figure (4.15 a, b) show the contaminated fingerprint tramadol sample real spectrum stored in the device library, and the sample data of the same examined fingerprint by the (GC-MS) device, respectively.

A clear match between the two charts, the highest peak of both charts appears at time 13.8 (min), the data says that the percentage of congruence is 68%. Also, the obtained data have showed that the examined fingerprint contain tramadol substance Table (4.8).

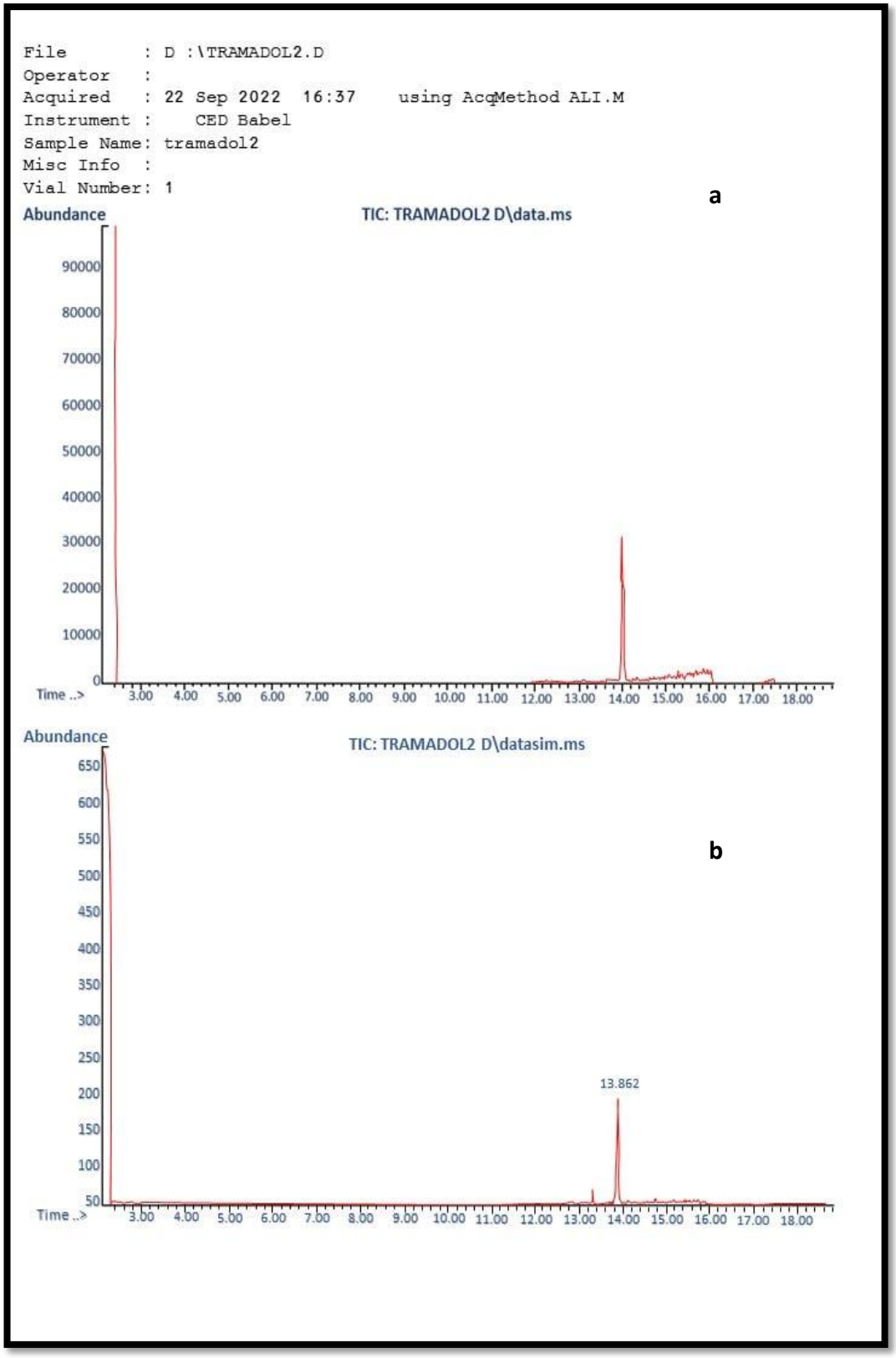


Figure 4.15: (a) Real TR fingerprint sample stored in the device,

(b) Examined sample of the same fingerprint.

Table 4.8: The data of TR fingerprint.

Name	Tamadol
Molecular Formula	$C_{16}H_{25}No_2$
Match Quality	68
Molecular Weight	263.19 gm

Table 4.9: The readings of the TR samples that were examined by the (GC-MS) device.

Shape of sample	Time (min)	Abundance
Powder	13.855	260
Fingerprint	13.832	220

4.6 TR Analysis Using Raman Spectroscopy:

The last step in this work, we examined tramadol by Raman spectroscopy. Where the Raman spectrum of a sample of tramadol powder was as shown in Figure (4.16), where we notice the appearance of the Raman shift at (200-800) cm^{-1}

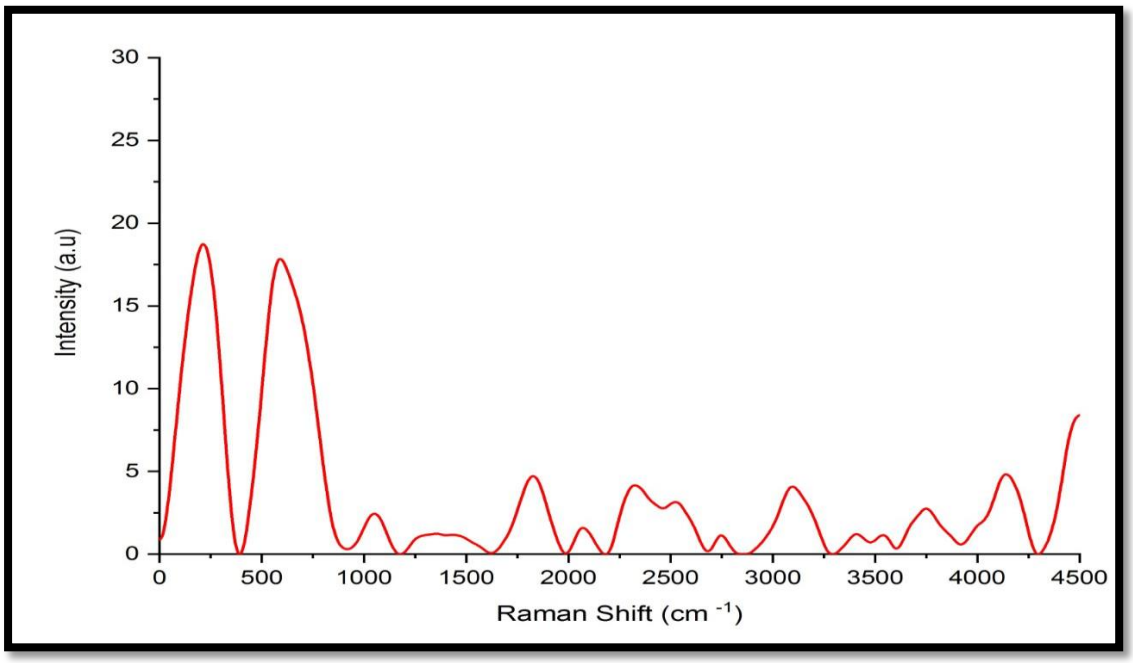


Figure 4.16: The Raman spectrum of TR powder sample.

On the other hand, the Raman spectrum of a fingerprint sample contaminated with the powder of the same substance appears in Figure (4.17), where the highest peak of this spectrum appeared in the range (200- 700) cm^{-1}

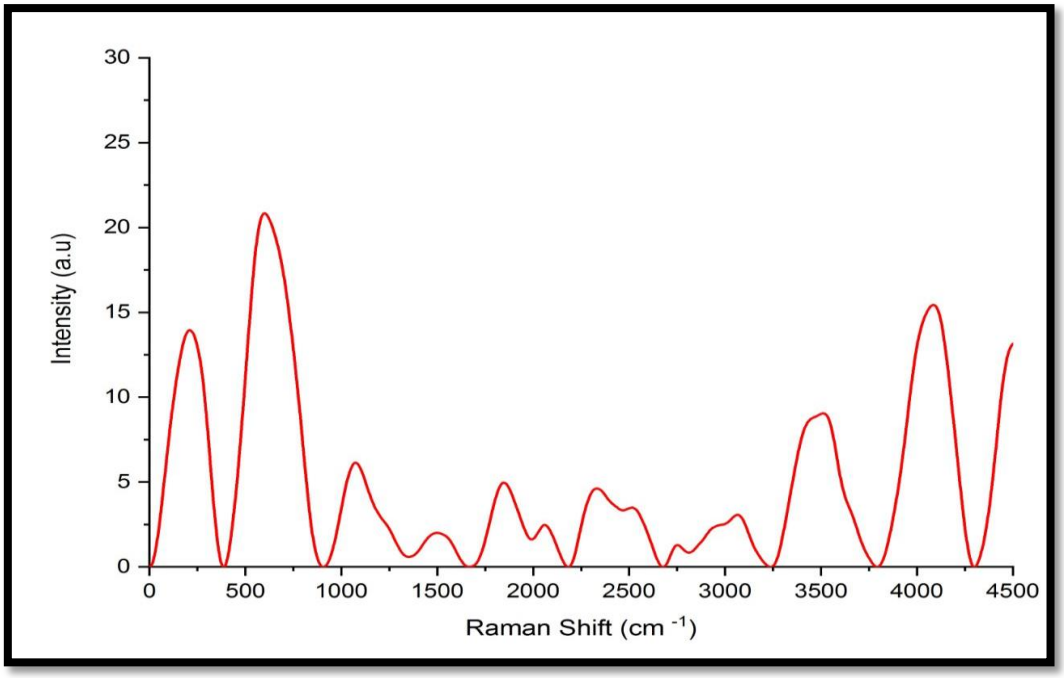


Figure 4.17: The Raman spectrum of a fingerprint sample contaminated with TR powder.

4.7 Conclusions

Through this research we conclude the following :-

1. The results a clear match between the powder and fingerprint samples using GC-MS device.
2. The sensitivety of GC-MS technique is cabable to detectd a small amount of drug materials as well as their molecular formula and molecular weight .
3. The results of Raman spectroscopy showed an approximate match between the sample of the anesthetic powder and the sample of the fingerprint contaminated with the same anesthetic powder .
4. The sensitivety of Raman spectroscopy is cabable to detectd a small amount of drug materials .
5. The GC-MS Spectrum showed sutable and accurate measurements compared to a Raman spectroscopy.

4.8 Future Work

1. Doing another study to find out the effect of drugs on the size of the distance between the fingerprint lines of drug addicts.
2. Examination of other drugs such as cannabis and cocaine by means of Raman apparatus and gas chromatography coupled with mass spectrometry.
3. Examination of types of psychotropic substances by means of (GC-MS) and Raman device to know the sensitivity of these devices to such substances.

References

[1] Day, J. S., Edwards, H. G., Dobrowski, S. A., & Voice, A. M. (2004). The detection of drugs of abuse in fingerprints using Raman spectroscopy I: latent fingerprints. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 60(3), 563-568.

[2] Yamashita, B., & French, M. (2010). Fingerprint Sourcebook-Chapter 7: Latent Print Development..

[3] Sahil, K., Prashant, B., Akanksha, M., Premjeet, S., & Devashish, R. (2011). Gas chromatography-mass spectrometry: applications. International journal of pharmaceutical & biological archives, 2(6), 1544-1560.

[4] Jenke, D. R. (1997). Chromatographic method validation: a review of current practices and procedures. I. General Concepts and Guidelines. Instrumentation science & technology, 25(4), 345-359.

[5]Smith, E., & Dent, G. (2019). Modern Raman spectroscopy: a practical approach. John Wiley & Sons.

[6] Larkin, P. (2017). Infrared and Raman spectroscopy: principles and spectral interpretation. Elsevier.

[7] Cuccia, L., Dugay, J., Bontemps, D., Louis-Louisy, M., & Vial, J. (2018). Analytical methods for the monitoring of post-combustion CO2 capture process using amine solvents: A review. International Journal of Greenhouse Gas Control, 72, 138-151.

[8] Kitson, F. G., Larsen, B. S., & McEwen, C. N. (1996). Gas chromatography and mass spectrometry: a practical guide. Academic Press.

[9] Black, I., Heiss, C., & Azadi, P. (2019). Comprehensive monosaccharide composition analysis of insoluble polysaccharides by permethylation to produce methyl alditol derivatives for gas chromatography/mass spectrometry. Analytical chemistry, 91(21), 13787-13793.

[10] Fang, M., Ivanisevic, J., Benton, H. P., Johnson, C. H., Patti, G. J., Hoang, L. T., ... & Siuzdak, G. (2015). Thermal degradation of small molecules: a global metabolomic investigation. Analytical chemistry, 87(21), 10935-10941.

[11] Raman, C. V., & Krishnan, K. S. (1928). A new type of secondary radiation. Nature, 121(3048), 501-502.

[12] Ng, P. H. R., Walker, S., Tahtouh, M., & Reedy, B. (2010). Detection of illicit substances in fingerprints by infrared spectral imaging. Analytical and bioanalytical chemistry, 394(8), 2039-2048.

[13] Hazarika, P., & Russell, D. A. (2012). Advances in fingerprint analysis. Angewandte Chemie International Edition, 51(15), 3524-3531.

[14] Cappelle, D., Yegles, M., Neels, H., van Nuijs, A. L., De Doncker,

M., Maudens, K., ... & Crunelle, C. L. (2015). Nail analysis for the detection of drugs of abuse and pharmaceuticals: a review. Forensic Toxicology, 33(1), 12-36.

[15] de Oliveira Penido, C. A. F., Pacheco, M. T. T., Lednev, I. K., & Silveira Jr, L. (2016). Raman spectroscopy in forensic analysis: identification of cocaine and other illegal drugs of abuse. Journal of Raman Spectroscopy, 47(1), 28-38.

[16] Costa, C. (2017). Development of a Confirmatory Test for Cocaine and Metabolites in Latent Fingerprints. University of Surrey (United Kingdom).

[17] Darwish, R. T. S., El Demellawy, M. A. M., Megahed, H. M. A. E. S., Younan, D. N., & Kholeif, W. S. A. E. R. (2017). detection of some drugs of abuse from fingerprint using liquid chroamtographyamss spectrometer. The Egyptian Journal of Forensic Sciences and Applied Toxicology, 17(2), 73-91.

[18] Khandasammy, S. R., Fikiet, M. A., Mistek, E., Ahmed, Y., Halámková, L., Bueno, J., & Lednev, I. K. (2018). Bloodstains, paintings, and drugs: Raman spectroscopy applications in forensic science. Forensic Chemistry, 8, 111-133.

[19] Abd Eldayed, A., & Abd Elaziz, M. (2018). Detection of drugs of abuse among drivers in Fayoum City/Egypt. Ain Shams Journal of Forensic Medicine and Clinical Toxicology, 31(2), 94-99.

[20] Yaser Z. Tawffeq, (2020). Effect of Some Associated Materials with Fingerprints using Raman Spectrometer. University of Babylon.

[21] Kumar, P., Sharma, A., Kumar, D., & Sharma, L. (2021). Use of Spectroscopic Methods and their clinical applications in drug abuse: A review. Critical Reviews in Analytical Chemistry, 1-14.

[22]Amin, M. O., Al-Hetlani, E., & Lednev, I. K. (2022). Detection and identification of drug traces in latent fingermarks using Raman spectroscopy. Scientific Reports, 12(1), 1-9.

[23] Kanani, H., Chrysanthopoulos, P. K., & Klapa, M. I. (2008). Standardizing gc–ms metabolomics. Journal of Chromatography B, 871(2), 191-201.

[24] Pasikanti, K. K., Ho, P. C., & Chan, E. C. Y. (2008). Gas chromatography/mass spectrometry in metabolic profiling of biological fluids. Journal of Chromatography B, 871(2), 202-211.

[25] Kiefer, W., & Long, D. A. (1982). Non-linear Raman Spectroscopy and its Chemical Applications: General Introduction To Non-linear Raman Spectroscpy. D. Reidel, England.

[26] Norman, P. (1998). Nonlinear Optical Properties of Fullerenes, Oligomers, and Solutions (Doctoral dissertation, Linköping University).

[27] Castner Jr, E. W. (2005). Modern spectroscopy, (j. michael hollas).

[28] Tolles, W. M., Nibler, J. W., McDonald, J. R., & Harvey, A. B.

(1977). A review of the theory and application of coherent anti-Stokes Raman spectroscopy (CARS). Applied Spectroscopy, 31(4), 253-271.

[29] Schweiger, G. (1990). Raman scattering on single aerosol particles and on flowing aerosols: a review. Journal of aerosol science, 21(4), 483-509.

[30] Knoll, P., Marchl, M., & Kiefer, W. (1988). Raman-spectroscopy of microparticles in laser-light traps. INDIAN JOURNAL OF PURE & APPLIED PHYSICS, 26(2-3), 268-277.

[31] Mohammed, A., Ågren, H., & Norman, P. (2009). Resonance enhanced Raman scattering from the complex electric-dipole polarizability: A theoretical study on N2. Chemical Physics Letters, 468(4-6), 119-123.

[32] Williams, T. M., & Worthy, G. A. (2002). Anatomy and physiology: the challenge of aquatic living. Marine mammal biology: An evolutionary approach, 73-97.

[33] Metze, D., Luger, T., Freinkel, R. K., & Woodley, D. T. (2001). Nervous system in the skin: new basic science in dermatology. The biology of the skin. New York, NY.: Parthenon Publishing Group, 153-65.

[34] Rodwell, V. W. (2015). Harper's illustrated biochemistry. McGraw-Hill Education.

[35] Lee, H. C., Ramotowski, R., & Gaensslen, R. E. (2001). Advances in Fingerprint Technology, Forensic and Police Science Series.

[36] Scruton, B., Robins, B. W., & Blott, B. H. (1975). The deposition of fingerprint films. Journal of Physics D: Applied Physics, 8(6), 714.

[37] Shea, J. J. (1998). Handbook of instrumental techniques for analytical chemistry. IEEE Electrical Insulation Magazine, 14(6), 42-42.

[38] Alyar, S., Şen, T., Özmen, Ü. Ö., Alyar, H., Adem, Ş., & Şen, C. (2019). Synthesis, spectroscopic characterizations, enzyme inhibition, molecular docking study and DFT calculations of new Schiff bases of sulfa drugs. Journal of Molecular Structure, 1185, 416-424.

[39] Kwong, A. V. (2017). Detection of humidity-treated aged latent prints using cyanoacrylate fuming and a reflected ultraviolet imaging system (RUVIS) (Doctoral dissertation, Boston University).

[40] Chogale, M. M., Ghodake, V. N., & Patravale, V. B. (2016). Performance parameters and characterizations of nanocrystals: A brief review. Pharmaceutics, 8(3), 26.

[41] Tveito, A., & Lines, G. T. (2016). Computing characterizations of drugs for ion channels and receptors using Markov models (p. 261). Springer Nature.

[42] Atanasov, A. G., Waltenberger, B., Pferschy-Wenzig, E. M., Linder, T., Wawrosch, C., Uhrin, P., ... & Stuppner, H. (2015). Discovery and resupply of pharmacologically active plant-derived natural products: A review. Biotechnology advances, 33(8), 1582-1614.

[43] Niewoehner, D. E., Rice, K., Cote, C., Paulson, D., Cooper Jr, J. A. D., Korducki, L., ... & Kesten, S. (2005). Prevention of exacerbations of chronic obstructive pulmonary disease with tiotropium, a once-daily inhaled anticholinergic bronchodilator: a randomized trial. Annals of internal medicine, 143(5), 317-326.

[44] Mahoney, A., & Evans, J. (2008, November). Comparing drug classification systems. In AMIA... Annual Symposium proceedings. AMIA Symposium (pp. 1039-1039).

[45] Wettermark, B., Elseviers, M., Almarsdóttir, A. B., Andersen, M., Benko, R., Bennie, M., ... & Vlahović-Palčevski, V. (2016). Introduction to drug utilization research. Drug utilization research: methods and applications, 1-12.

[46] Bergström, C. A., Andersson, S. B., Fagerberg, J. H., Ragnarsson, G., & Lindahl, A. (2014). Is the full potential of the

biopharmaceutics classification system reached?. European Journal of Pharmaceutical Sciences, 57, 224-231.

[47] Pedersen, J. (2015). Increasing productivity in software testing: Visualizing and managingarbitrarily structured messages and message queues to increase productivity andusability.

[48] Crocq, M. A. (2022). Alcohol, nicotine, caffeine, and mental disorders. Dialogues in clinical neuroscience.

[49] Chiappini, S., & Schifano, F. (2016). A decade of gabapentinoid misuse: an analysis of the European Medicines Agency's 'Suspected Adverse Drug Reactions' database. CNS drugs, 30(7), 647-654.

[50] Fox, T. P., Oliver, G., & Ellis, S. M. (2013). The destructive capacity of drug abuse: An overview exploring the harmful potential of drug abuse both to the individual and to society. International Scholarly Research Notices, 2013.

[51] MacKillop, J., Murphy, J. G., Tidey, J. W., Kahler, C. W., Ray, L. A., & Bickel, W. K. (2009). Latent structure of facets of alcohol reinforcement from a behavioral economic demand curve. Psychopharmacology, 203(1), 33-40.

[52] Sorribes-Soriano, A., Esteve-Turrillas, F. A., Armenta, S., Amorós, P., & Herrero-Martínez, J. M. (2019). Amphetamine-type stimulants analysis in oral fluid based on molecularly imprinting extraction. Analytica chimica acta, 1052, 73-83.

[53] Edeleano, L. (1887). Ueber einige Derivate der Phenylmethacrylsäure und der Phenylisobuttersäure. Berichte der deutschen chemischen Gesellschaft, 20(1), 616-622.

[54] Sulzer, D., Sonders, M. S., Poulsen, N. W., & Galli, A. (2005). Mechanisms of neurotransmitter release by amphetamines: a review. Progress in neurobiology, 75(6), 406-433.

[55] Grobler, S. R., Chikte, U., & Westraat, J. (2011). The pH levels of different methamphetamine drug samples on the street market in Cape Town. International Scholarly Research Notices.

[56] Rasmussen, N. (2008). On speed. In On Speed. New York University Press.

[57] Hurst, F. (2013). WWII Drug: The German Granddaddy of Crystal Meth. Spiegel Online, 30..

[58] Estrada, A., Kelley, A. M., Webb, C. M., Athy, J. R., & Crowley, J. S. (2012). Modafinil as a replacement for dextroamphetamine for sustaining alertness in military helicopter pilots. Aviation, space, and environmental medicine, 83(6), 556-567.

[59] Wigal, S. B. (2009). Efficacy and safety limitations of attention-deficit hyperactivity disorder pharmacotherapy in children and adults. CNS drugs, 23(1), 21-31.

[60] Willcutt, E. G. (2012). The prevalence of DSM-IV attention-deficit/hyperactivity disorder: a meta-analytic review. Neurotherapeutics, 9(3), 490-499.

[61] Bazzano, A. T., Mangione-Smith, R., Schonlau, M., Suttorp, M. J., & Brook, R. H. (2009). Off-label prescribing to children in the United States outpatient setting. Academic pediatrics, 9(2), 81-88.

[62] Hsu, J., Lin, J. J., & Tsay, W. I. (2014). Analysis of drug abuse data reported by medical institutions in Taiwan from 2002 to 2011. journal of food and drug analysis, 22(2), 169-177.

[63] Mitler, M. M., Hajdukovic, R., & Erman, M. K. (1993). Treatment of narcolepsy with methamphetamine. Sleep, 16(4), 306-317.

[64] Frances, R. J., Miller, S. I., & Mack, A. H. (Eds.). (2005). Clinical textbook of addictive disorders. Guilford Press.

[65] Logan, B. K. (2002). Methamphetamine-effects on human performance and behavior. Forensic Science Review, 14(1), 133-151.

[66] Cruickshank, C. C., & Dyer, K. R. (2009). A review of the clinical pharmacology of methamphetamine. Addiction, 104(7), 1085-1099.

[67] Barr, A. M., Panenka, W. J., MacEwan, G. W., Thornton, A. E., Lang, D. J., Honer, W. G., & Lecomte, T. (2006). The need for speed: an update on methamphetamine addiction. Journal of Psychiatry and Neuroscience, 31(5), 301-313.

[68] Darke, S., Kaye, S., McKetin, R., & Duflou, J. (2008). Major physical and psychological harms of methamphetamine use. Drug and alcohol review, 27(3), 253-262.

[69] Vazzana, M., Andreani, T., Fangueiro, J., Faggio, C., Silva, C., Santini, A., ... & Souto, E. B. (2015). Tramadol hydrochloride: pharmacokinetics, pharmacodynamics, adverse side effects, co-administration of drugs and new drug delivery systems. Biomedicine & Pharmacotherapy, 70, 234-238.

[70] Seifi, M., Moghadam, M. H., Hadizadeh, F., Ali-Asgari, S., Aboli, J., & Mohajeri, S. A. (2014). Preparation and study of tramadol imprinted micro-and nanoparticles by precipitation polymerization: Microwave irradiation and conventional heating method. International Journal of Pharmaceutics, 471(1-2), 37-44.

[71] Aamir, M. N., Ahmad, M., Akhtar, N., Murtaza, G., Khan, S. A., & Nokhodchi, A. (2011). Development and in vitro–in vivo relationship of controlled-release microparticles loaded with tramadol hydrochloride. International journal of pharmaceutics, 407(1- 2), 38-43.

[72] gounder Subramanian, K., & Vijayakumar, V. (2012). Synthesis and evaluation of chitosan-graft-poly (2-hydroxyethyl methacrylate-co-itaconic acid) as a drug carrier for controlled release of tramadol hydrochloride. Saudi Pharmaceutical Journal, 20(3), 263-271.

[73] Souto, E. B., & Doktorovova, S. (2009). Solid lipid nanoparticle formulations: pharmacokinetic and biopharmaceutical aspects in drug delivery. Methods in Enzymology, 464, 105-129.

[74] Chen, Y., Zhou, A., Liu, B., & Liang, J. (2010). Tramadol hydrochloride/montmorillonite composite: Preparation and controlled drug release. Applied Clay Science, 49(3), 108-112..

[75] Subedi, A., Biswas, B. K., Tripathi, M., Bhattarai, B. K., & Pokharel, K. (2013). Analgesic effects of intrathecal tramadol in patients undergoing caesarean section: a randomised, double-blind study. International journal of obstetric anesthesia, 22(4), 316-321.

[76] Cialdai, C., Giuliani, S., Valenti, C., Tramontana, M., & Maggi, C. A. (2013). Comparison between oral and intra-articular antinociceptive effect of dexketoprofen and tramadol combination in monosodium iodoacetate-induced osteoarthritis in rats. European journal of pharmacology, 714(1-3), 346-351.

[77] Lee, J. H., Lee, C. S., & Ultracet ER Study Group. (2013). A randomized, double-blind, placebo-controlled, parallel-group study to evaluate the efficacy and safety of the extended-release tramadol hydrochloride/acetaminophen fixed-dose combination tablet for the treatment of chronic low back pain. Clinical therapeutics, 35(11), 1830-1840.

[78] Cox, S., Villarino, N., & Doherty, T. (2010). Determination of oral tramadol pharmacokinetics in horses. Research in veterinary science, 89(2), 236-241.

[79] Umar, Y., Abdalla, S., Haque, S. M., Moran, G. S., Ishaq, A., Villada, W. C., ... & Bunster, M. (2020). Theoretical investigation of the molecular structure, vibrational spectra, and molecular docking of tramadol using density functional theory. Journal of the Chinese Chemical Society, 67(1), 62-71.

[80] Mondello, L., Tranchida, P. Q., Dugo, P., & Dugo, G. (2008). Comprehensive two-dimensional gas chromatography-mass spectrometry: A review. Mass spectrometry reviews, 27(2), 101-124.