SHIMADZU
Excellence in Science

Analytical Instruments

Solutions for Forensic Toxicology

At Shimadzu, we have the analytical tools necessary for your forensic toxicology laboratory to be accurate, efficient, and confident with your results. Our products cover anything from sample preparation to screening, identification and confirmation. In addition, our wide range of instrumentation can be used with a variety of sample types, such as whole blood, urine, plasma, oral fluids, postmortem, tissues, etc.

Table of Contents

Drug Screening, Confirmation, and Quantitation of Biological Samples

Drug screening, qualitative confirmation/identification and quantitation are the three main categories used for forensic toxicology methods, as described by SWGTOX guidelines (2013) and the OSAC committees. Shimadzu offers many different analytical solutions to assist with each of these categories.

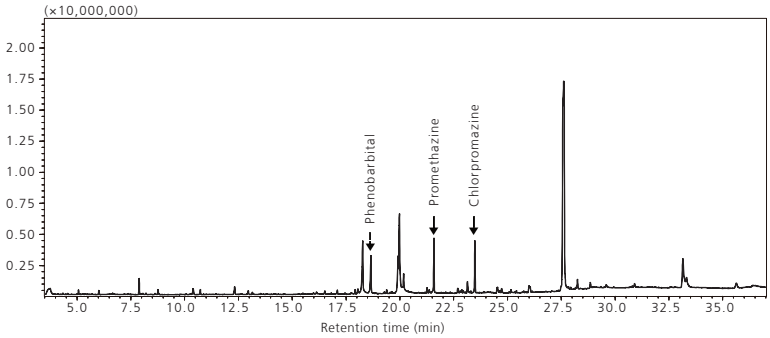
Screening, Confirmation, and Quantitation by GC-MS

Single Quadrupole Mass Spectrometer GCMS-QP2020 NX

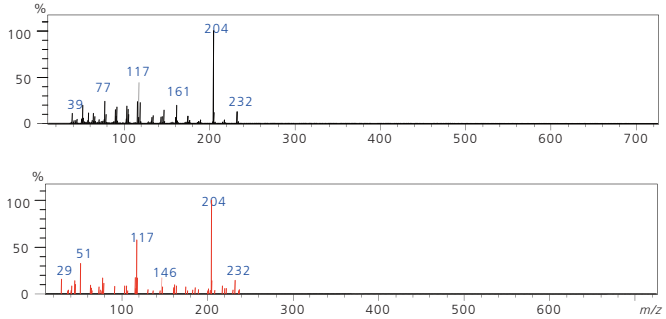
GC-MS methods have been used in forensic toxicology labs for many years and a GC-MS is the most common analytical instrument found in these laboratories. Adopting a proprietary multi-function ion source, large-capacity turbomolecular pump with heightened exhaust efficiency for all carrier gases, including nitrogen, and Advanced Scanning Speed Protocol, the GCMS-QP2020 NX is the gold standard for routine drug analysis for both screening and confirmation.

Analysis of Psychotropic Drugs in Serum Using GC-MS

The number of deaths due to abuse and overuse of stimulants and other illegal drugs continues to be a major societal issue. This GC-MS application shows how the GCMS-QP2020 NX is able to identify three common drugs: phenobarbital, chlorpromazine and promethazine, in serum using library searching and matching.



Total Ion Current Chromatogram Obtained from Spiked Serum



Comparison of Measured Mass Spectrum of Phenobarbital (above) and Standard Mass Spectrum (below)

Column used: SH-RXI-5Sil MS

Screening, Confirmation, and Quantitation by LC-MS/MS

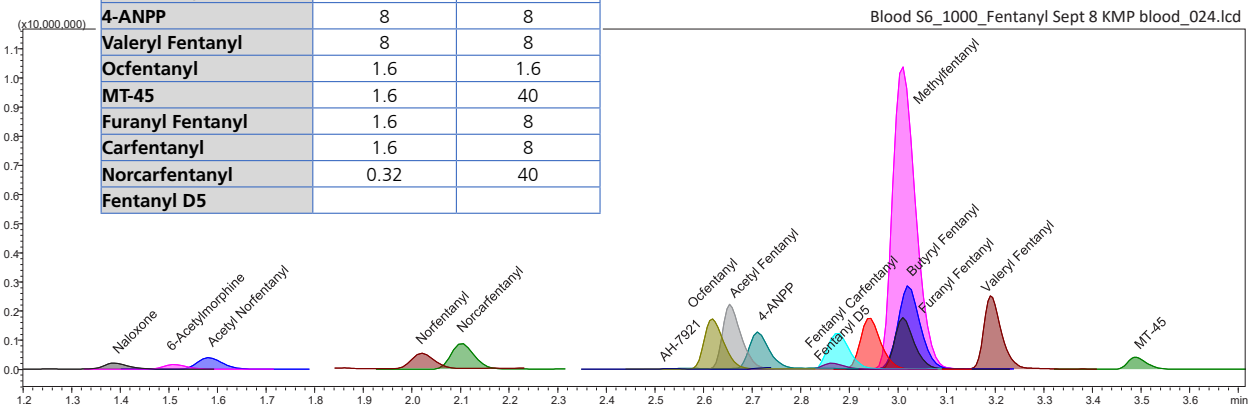
Triple Quadrupole Mass Spectrometer LCMS-8045/8050/8060

Our LCMS triple quadrupole series, with the fastest scanning speeds in the market, allows for quick MRM screening with triggered product ion scanning to provide more confident and accurate results. Shimadzu offers three different triple quadrupole models to satisfy the appropriate sensitivity needed for analysis. Our most sensitive triple quadrupole, the LCMS-8060 can be used to quantitate very low levels of analytes, such as fentanyl and fentanyl analogs, in complex biological matrices.

Compound	Blood LOD (pg/mL)	Urine LOD (pg/mL)
Methylfentanyl	1.6	40
6-Acetylmorphine	1.6	40
Naloxone	200	8
Fentanyl	8	8
Acetyl Fentanyl	1.6	40
Butyryl Fentanyl	8	40
Norfentanyl	0.32	8
4-ANPP	8	8
Valeryl Fentanyl	8	8
Ocfentanyl	1.6	1.6
MT-45	1.6	40
Furanyl Fentanyl	1.6	8
Carfentanyl	1.6	8
Norcarfentanyl	0.32	40
Fentanyl D5		

Quantitative Detection of Fentanyl and Related Synthetic Opioids in Biological Matrices

A single LC-MS/MS method was developed using the LCMS-8060 to identify and quantify a limit of detection (LOD) for fentanyl and related synthetic opioids in both blood and urine samples. An example chromatogram and LODs for each compound are shown below.

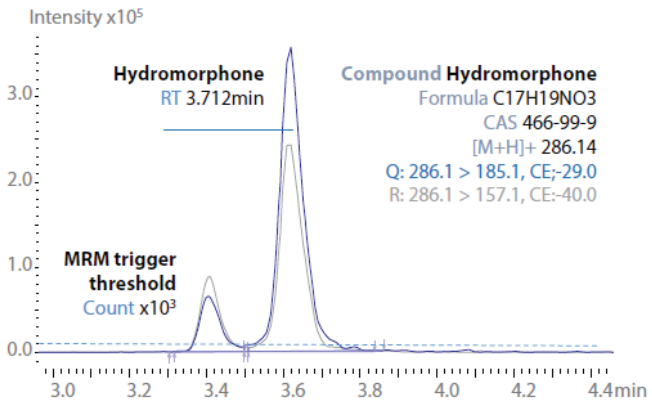


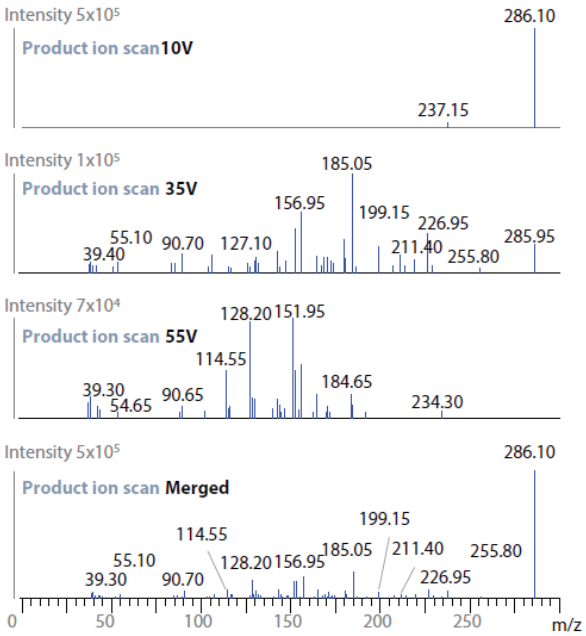
Column used: Shim-pack Velox Biphenyl

Targeted Screening with Library Searching of Drugs of Abuse

The LCMS triple quadrupole instruments have the capability of doing MRM triggered product ion scans to provide more accurate and additional information for all analytes of interest. This allows one to perform targeted screening to be more confident with the results especially when in a court of law.

Below and to the right are examples of MRM triggered analysis for hydromorphone. Above a predefined MRM intensity threshold, product ion scans are triggered to acquire scan data at different collision energies (10, 35 and 55 V). For library-based identification, the product ion scans from each collision energy are merged together.





Automated Sample Prep for LC-MS

Automated Sample Prep Module CLAM-2030

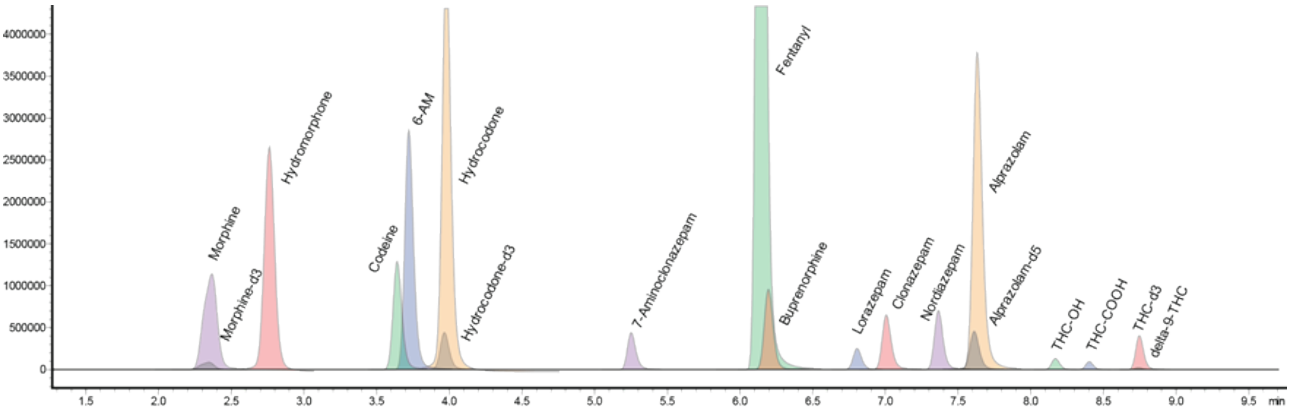
The CLAM (Clinical Laboratory Automation Module) offers a new, hands-free approach for drug analysis in biological matrices using LC-MS. The module, when coupled with an LC-MS, increases sample throughput, minimizes human error and increases overall safety.

Analysis of Postmortem Samples

Quantitative analysis results of postmortem samples obtained after automated (CLAM) and manual sample preparation are summarized in the table below. Sample preparation time was reduced from over 2 hours to 5 min when switching from manual to automated sample preparation, increasing throughput tremendously. RSD of triplicate injections (automated preparation) are included with values less than 10% for all but one sample.

Sample ID	Postmortem Specimen	Drugs found above 10 ng/mL cutoff	Results from manual preparation (ng/mL)	CLAM with LCMS-8060 results (ng/mL)				Average % difference between manual prep and CLAM
				Rep 1	Rep 2	Rep 3	%RSD	
A	Heart blood	Morphine	400	446.1	445.4	442.1	**0.476**	11%
		Codeine	19	22.3	20.9	21.2	**3.478**	13%
		Alprazolam	593	557.9	558.1	557.7	**0.043**	-6%
B	Chest cavity blood	Morphine	363	373	365.1	369.7	**1.071**	2%
		Codeine	31	31.9	32.3	33.2	**1.952**	5%
		Nordiazepam	135	154.8	149.5	156.2	**2.317**	14%
C	Femoral blood	Hydrocodone	177	175.9	177.9	174.2	**1.048**	-1%
		Hydromorphone	30	30.3	29.9	30.8	**1.438**	1%
D	Heart blood	7-aminoclonazepam	72	48.5	47.7	46.4	**2.147**	-34%
E	Heart blood	THC-COOH	Detected*	42.2	42.3	49.9	**9.937**	n/a
F	Spleen** (ng/g) homogenate dil. factor = 5	Morphine	493	493.7	457.1	347.7	**17.551**	-12%
G	Brain** (ng/g) homogenate dil. factor = 5	Morphine	147	169.7	168.9	176.6	**2.46**	17%

*THC quantification not part of laboratory assays.
**Blank tissues were not used for calibration curve preparation and results were based off the blank blood curve. Brain and spleen were from the same case file.



Column used: Shim-pack Velox Biphenyl

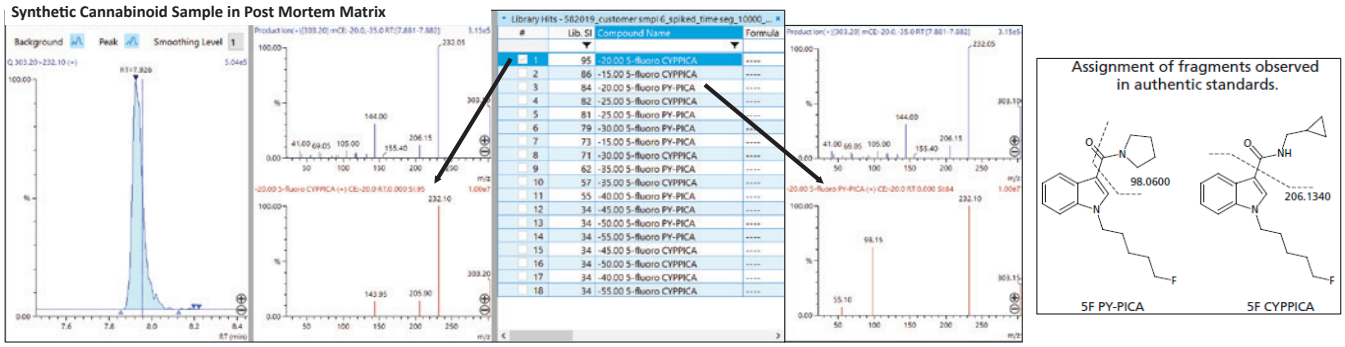
Screening by Q-TOF LC-MS

Q-TOF Mass Spectrometer LCMS-9030

Shimadzu's research-grade LCMS-9030 Q-TOF mass spectrometer combines the engineering DNA from our proven triple quadrupole (LC-MS/MS) platform with powerful new TOF architecture to transform high mass accuracy workflows. The result is a system that delivers high-resolution, accurate-mass detection with incredibly fast data acquisition rates for untargeted analysis of unknown compounds.

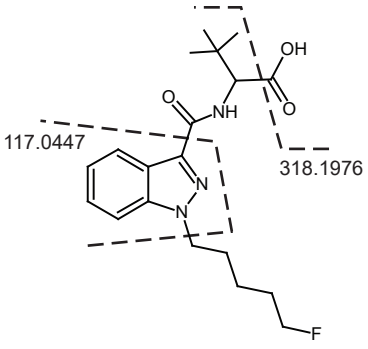
High Resolution Screening of Synthetic Cannabinoids

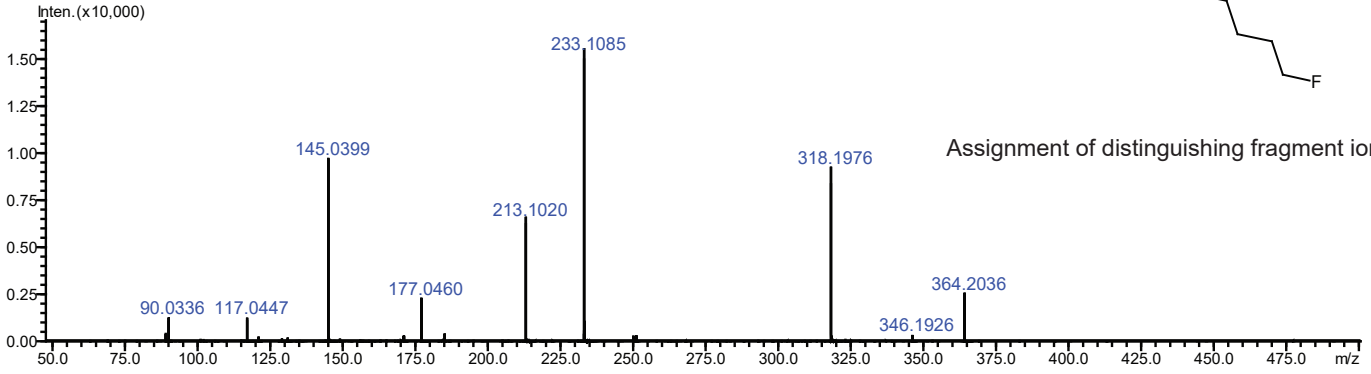
Over 300 authentic standards were analyzed by the LCMS-9030 to create a high-resolution tandem mass spectrum library and screening method. Postmortem samples were screened for the presence of synthetic cannabinoids. The identified peaks were then compared to a known library to generate a similarity score which was used to properly identify the compound.



In the supplied postmortem sample, 5F-CYPPICA and 5F-PYPICA are differentiated from each other based on product ion scans. 5F-CYPPICA was identified as being present in the sample with a similarity score of 95 from the Library Search, compared to a similarity score of only 84 for 5F-PYPICA.

In addition to screening compounds and comparing to a library, one can use the built-in formula prediction tool to assign MS/MS fragmentation patterns to a specific compound. In this example, formula prediction was done on the chromatographic peak at m/z 364.20371, which matched to 910 hits in a ChemSpider search. The data-dependent MS^2 spectrum showed the presence of an indazole core group, narrowing the number of hits to just 5 structures. The only structure consistent with the full MS^2 pattern was 5F-ADB Metabolite 7





Assignment of distinguishing fragment ions

Column used: Shim-pack Velox C18 or Shim-pack Velox Biphenyl

Heavy Metals Analysis

Long-term exposure and high dosage amounts of heavy metals can lead to poisoning and even death. It is important to have the proper analytical equipment to measure heavy metals in biological samples at low levels.

Inductively Coupled Plasma Mass Spectrometer ICPMS-2030

Ideal for efficient, accurate determination of trace elements, the ICPMS-2030 offers the industry's lowest running costs and the ultimate in ease of use with software assistant functions that significantly reduce data review time. In addition, an optimized internal structure leads to high stability, ultra-low detection limits, and low interference.

Measurement of Toxic Metals

The quantitation of toxic metals in biological samples such as blood and urine is necessary for assessing the exposure of humans and other animals to such metals through the natural environment, including consumption of metal-laden foods and drinks. An ICP-MS system is able to quickly measure trace quantities of toxic metals with high sensitivity.

Measured Element	As	Cd	Pb	Mn	Hg	Se
Mass Number	75	111	208	55	202	78
Analytical Value (µg/L)	2.4	0.36	10.2	20.7	1.50	59
Analytical Uncertainty (µg/L)	0.5	0.02	2.1	4.2	0.30	12
Quantitation Value (µg/L)	2.2	0.35	8.7	20.2	1.5	68

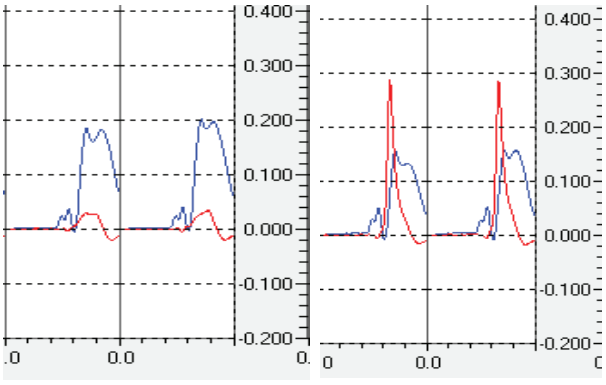
Measurement Results for Trace Elements in Blood

Atomic Absorption Spectrophotometer AA-7000 Series

The AA-7000 series spectrophotometer features high-sensitivity analysis, a flexible system configuration, and a compact footprint. When coupled with the graphite furnace atomizer, it allows for furnace analysis of trace samples.

Direct Determination of Lead (Pb) in Whole Blood

Detection of Pb in blood can be performed using several methods, such as AA or ICP-MS, depending on limits of detection, limit of quantitation and technical requirements. Shown here are peak profiles of whole blood (left) and whole blood spiked with 30 ppb Pb (right). The red trace is the sample and the blue trace is the background.



Volatile Drug Screening and Confirmation

Blood alcohol testing is an integral part of a forensic toxicologist's duties. It is important that one has the right instrumentation to generate accurate and reliable results for the measurement of ethanol in a person's blood at the time a sample is taken. The most widely used method to accurately measure blood alcohol content for impairment is using headspace sampling and dual column separation by gas chromatography with flame ionization detection.

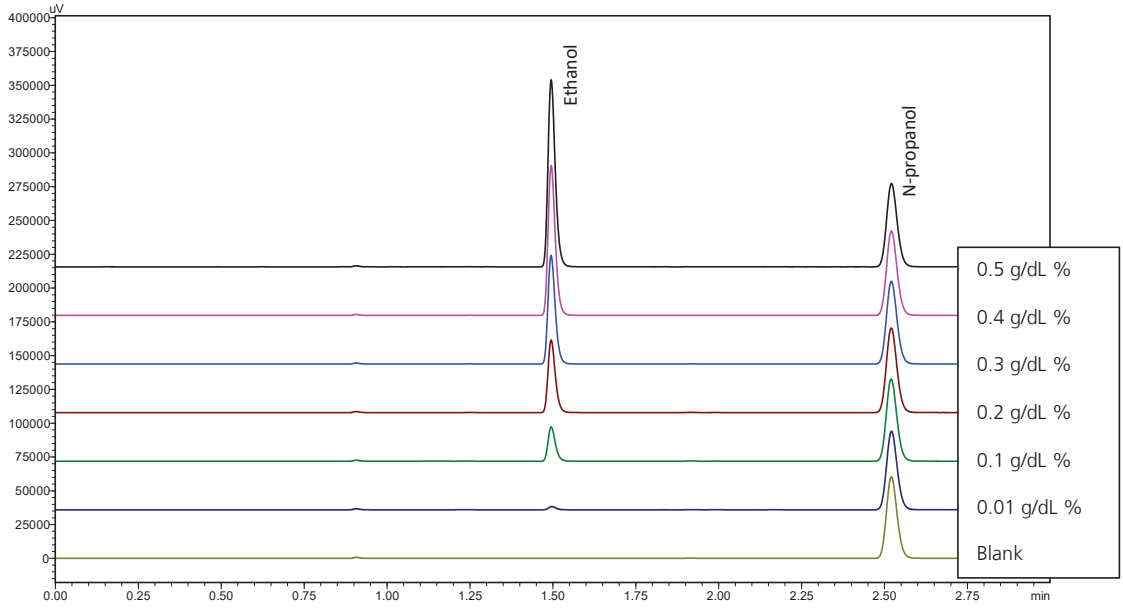
Shimadzu's Nexus GC-2030 with dual FID provides the solution for blood alcohol content. This can be coupled with our standalone HS-20 headspace autosampler .

Dual FID Gas Chromatograph with Headspace Sampler: Nexis GC-2030 / HS-20

The HS-20 Series consists of two models: a Loop model for the traditional static headspace methods, and a Trap model, which adds the dynamic headspace technique for applications requiring greater sensitivity. The series provides precise control of gas flow rates, and a mechanism that allows a sample vial to enter the oven from the bottom. This technique minimizes heat loss and thermal instability during the equilibration step. The HS-20 directly connects to the GC column with a standard nut and ferrule through the transfer line. The HS-20 series tray holds up to 90 sample vials. It accommodates both 10-mL and 20-mL headspace vials within the same sequence without the need for special attachments. The open architecture of the HS-20 tray provides easy access to all vials for loading and enables stress-free maintenance from the top of the instrument.

The Nexis GC-2030 has advanced flow technology, an intelligent flow controller and a user-friendly touch-panel interface. In addition, the Nexis GC-2030 uses either helium or hydrogen carrier gas with no additional system changes.

Using the Shimadzu Nexis GC-2030 with HS-20 loop headspace sampler, column splitting, and dual flame ionization detectors (FID), several parameters were tested for system and method optimization to meet the needs of blood alcohol analysis. The figure below shows an overlay comparison of 7 injections including a blank with the internal standard (N-propanol) and increasing concentrations of ethanol.



Columns used: H-RTX-BAC1 and SH-RTX-BAC2 (SH-RTX-BAC PLUS 1 and SH-RTX-BAC PLUS 2 can also be used)

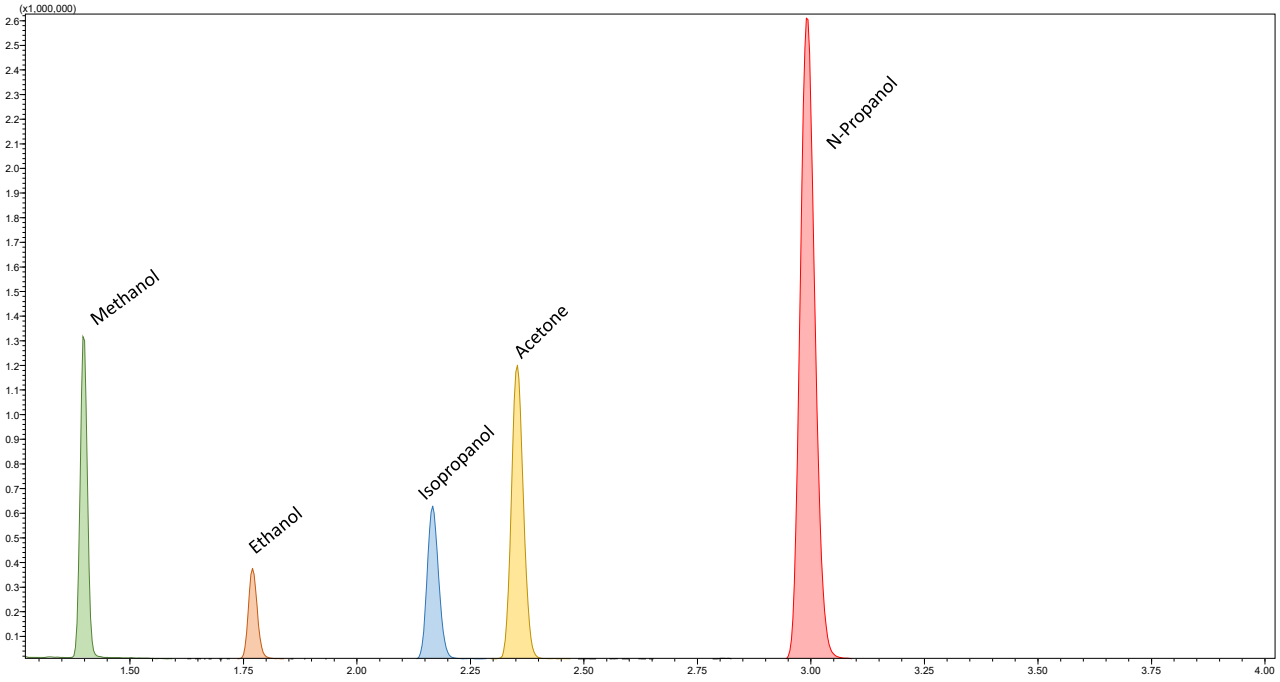
Single Quadrupole Headspace
Mass Spectrometer: GCMS-QP2020 NX / AOC-6000

Mass spectrometry is becoming more popular and well established in the forensic community. Although blood alcohol analysis has been done routinely by GC with dual FID, more laboratories are looking to add MS capability to their analysis with a GC-MS with FID system. This allows for a more confident level of confirmation by comparing not only retention time, but also matching the ethanol mass spectrum to a known standard from a mass spectrum library.

The AOC-6000 robotic autosampler enables multiple injection techniques: liquid, headspace, and solid-phase microextraction (SPME). It allows for sample preparation to be completely automated. With the ability to select different volumes and types of syringes, pretreatment by dilution, mixing or the addition of internal standards has never been easier. Additionally, the autosampler performs sample pretreatment and analysis in parallel so no time is lost during continuous analysis.

These features not only heighten the efficiency of complicated sample preparation, they also make it possible to prepare multi-point calibration standards from a stock solution and spike each with internal standards.

The figure below shows an example in which only two standards were prepared by the user – the stock calibration standard and internal standard. All other standards were prepared by the AOC-6000 autosampler and all samples were spiked with internal standard by the autosampler. All prep and analyses were run automatically in a continuous run.



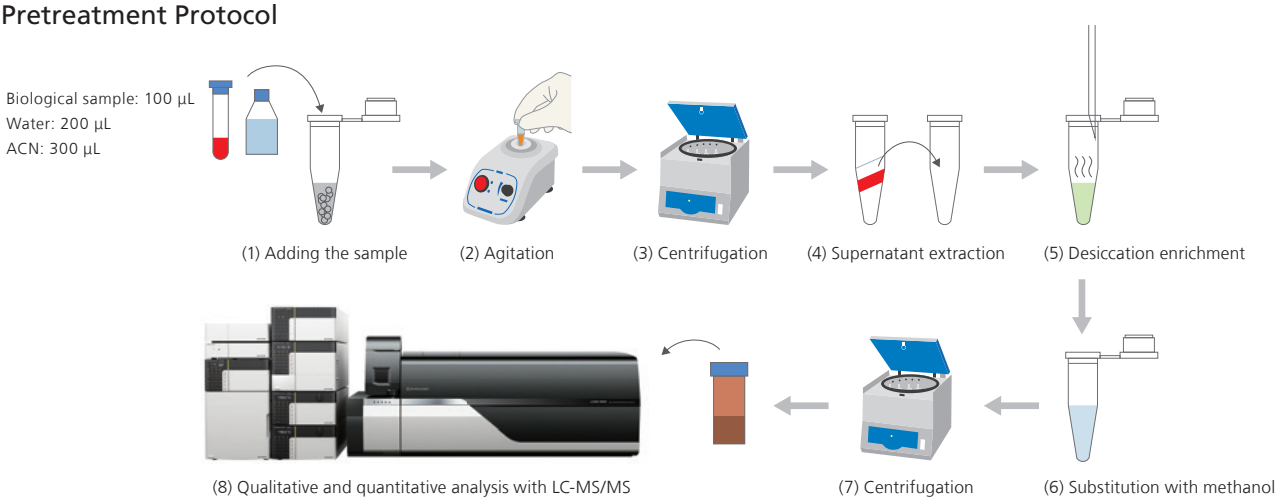
Columns used: H-RTX-BAC1 and SH-RTX-BAC2 (SH-RTX-BAC PLUS 1 and SH-RTX-BAC PLUS 2 can also be used)

Offline Sample Preparation

The key to accurate and reproducible quantitative data for forensic toxicology is good sample preparation, especially for different biological samples. The micro volume QuEChERS kits for LC-MS/MS are ready-to-use 2.0 mL micro tubes with 100 mg of QuEChERS salt pre-measured in the tubes.

This allows for a simple workflow, where one just adds the sample of interest (blood, plasma, urine, oral fluid, tissues, etc.), mixes with the salts and centrifuges the solution.

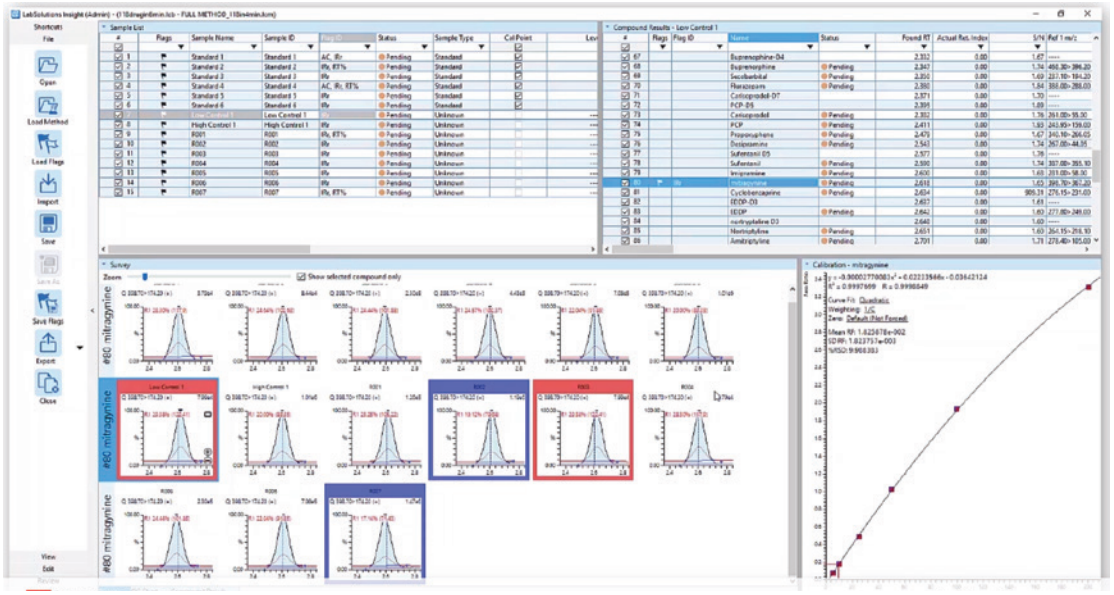
Pretreatment Protocol



Multi-Analyte Software

LabSolutions Insight multi-analyte quantitative software for both GC-MS and LC-MS/MS offers streamlined data analysis for more efficient and accurate results. The flag-based labeling and filtering allows users to only review outliers and have more confidence in the results that they provide as a part of the casework.

In addition, LabSolutions Insight has library screening to display qualitative data for LC-MS/MS on both the triple quadrupole and Q-TOF data.



Software Support

Shimadzu offers a variety of software databases to aid in your forensic toxicology needs for both GC-MS and LC-MS/MS products.

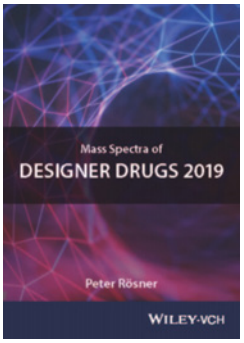
GCMS Forensic Toxicology Database

The GC-MS forensic toxicology database includes methods parameters as well as library information for a total of 2210 compounds, including illicit, psychotropic, and medical drugs.

GCMS Wiley Designer Drug Library

Contains the largest collection of chemical signatures of NPS and drugs of abuse in the world. The 2019 edition features the addition of over 1,500 new mass spectra and over 1,250 new, unique compounds in over 30 different classification groups such as fentanyls, synthetic cannabinoids, and opiates.

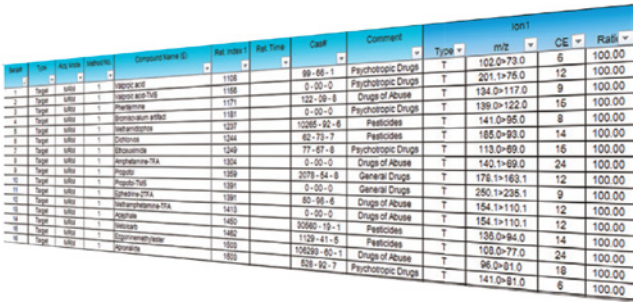
- Mass Spectra: 28,032
- Chemical Structures: 28,032
- Unique Compounds: 21,649
- Measured Kovats Indices: 18,017
- Opiates: 353
- Fentanyls: 866
- Cannibiminetics: 996
- Canniboids: 112
- Average Quality Index/Spectrum (QI): 950.0



GCMS Smart Forensic Database

Registered with a total of 201 forensic toxicological substances often involved in poisonings, such as drugs of abuse, psychotropic drugs, pharmaceuticals and pesticides, and including 1200 MRM transitions, it supports the creation of MRM methods for forensic toxicological substances.

Scan data obtained with simultaneous Scan/MRM measurements can be analyzed using the GC/MS Forensic Toxicological Database, which is used to screen for forensic toxicological substances.



LCMS Forensic Toxicology Database

The LC-MS/MS Forensic toxicology database includes optimized LC-MS/MS data acquisition parameters and a library database for over 2100 compounds to help forensic researchers build screening and quantitation methods quickly, simplifying method development and providing accuracy and confidence in screening results.

Consumables

Shimadzu has provided over 140 years of simplicity, elegance, and innovation to the scientific community, becoming the brand researchers trust. We have developed an extensive portfolio of the highest quality consumable products to ensure your work progresses effortlessly. Whether you need new columns for liquid or gas chromatography, isotopically labeled standards for mass spectrometry work, a leak detector for a gas chromatograph, syringes, filters, and vials for sample preparation, or one of hundreds of other laboratory consumables, Shimadzu has the solution.

Table of Analytical Instruments for Forensic Applications

	Toxicology - Screening	Toxicology - Confirmation/ Identification	Toxicology - Quant	Trace Evidence (Hairs/Fibers/ Paints/Arson)	Controlled Substances/Seized Drugs
GC		✓	✓		✓
GC-MS	✓	✓	✓	✓	✓
HS GC		✓	✓		
HS GC-MS		✓	✓		
Pyrolyzer GC-MS				✓	
FTIR				✓	✓
IR Microscope				✓	✓
UV-VIS				✓	✓
Fluorescence				✓	✓
SFC					✓
LC					✓
LC-MS Single Quad	✓				✓
LC-MS/MS Triple Quad	✓	✓	✓		
LC-MS (Q-TOF) High Resolution	✓	✓			
Automated Sample Prep	✓				
GF-AA		✓	✓	✓	
ICP-MS		✓	✓	✓	
XRD					✓
EDXRF				✓	

SHIMADZU

Shimadzu Corporation

www.shimadzu.com/an/

Shimadzu Scientific Instruments
7102 Riverwood Drive, Columbia, Maryland 21046, U.S.A.
Phone: 800-477-1227/410-381-1227, Fax: 410-381-1222

www.ssi.shimadzu.com