GC coupling to LC-MS instruments

Expand your mass spectrometric “view” with SICRIT®

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05.05.2020

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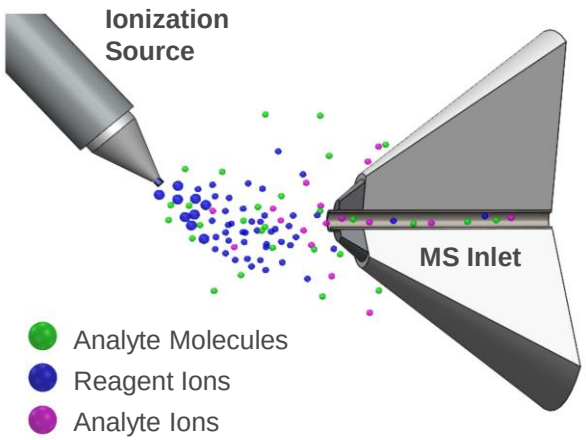
The patented flow-through geometry of the SICRIT® ionization source is new and unique

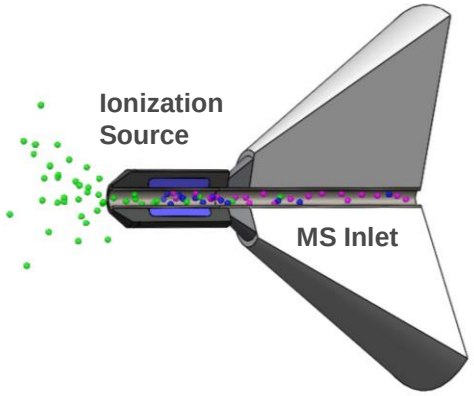
Conventional Ionization Technologies



With conventional atmospheric pressure methods, the **ions** are mostly **formed outside the inlet of an MS**. This implies that the sample (e.g. coffee) cannot be analyzed directly, but is usually "sprayed" into the MS in the form of a liquid extract via the ionization source

VS.

SICRIT® Technology



The SICRIT® (Soft Ionization by Chemical Reaction In Transfer) ionization source is **interfaced with** the atmospheric pressure **inlet of the MS** and ionizes every substance which is drawn into the MS by its inherent vacuum.

SICRIT® Characteristics

- **Simple extension** of MS inlet
- Concentric **dielectric barrier discharge**
- Sample **ionized during transfer** into MS
- **Soft ionization** by proton transfer and UV light
- **No consumables**

Reducing complexity of mass spectrometry in terms of preparation, execution and evaluation

Increased Sensitivity

The ionization within a closed chamber in extension of the inlet prevents columbic repulsion before the inlet and enables higher sensitivities

Enhanced Range of Analytes

Three simultaneous ionization mechanisms expand the range of detectable analytes, covering polar and non-polar components

No Sample Preparation

The ambient character of the ionization source allows to analyze solid, liquid, or gaseous samples in room air without sample preparation (direct screening)

Flexible Coupling

It is the only technique that provides a seamless coupling with all chromatography methods like GC, LC or SFC

No Fragmentation

The unique shape of the cold plasma enables a soft ionization of analytes and avoids fragmentation

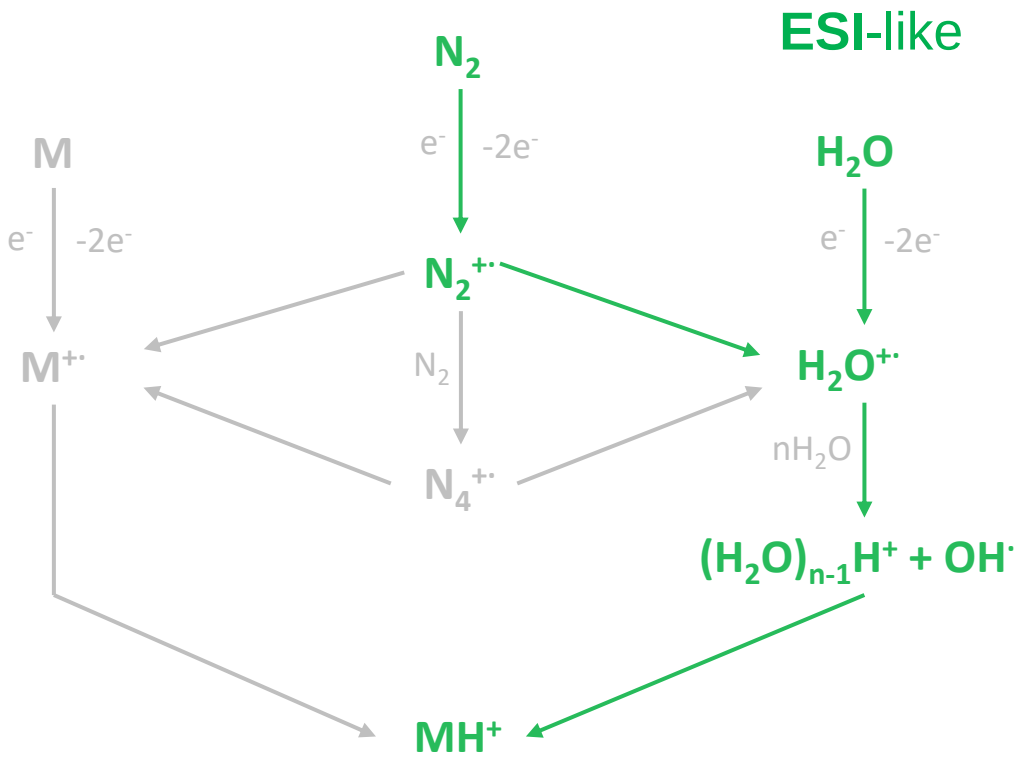
Detailed in the following

Applications

- Direct screening
- **GC/MS coupling**
- LC/MS coupling
- SFC/MS coupling
- Laser ablation imaging

Details per application available upon request

Three simultaneous ionization mechanisms expand the range of detectable analytes (1/3)

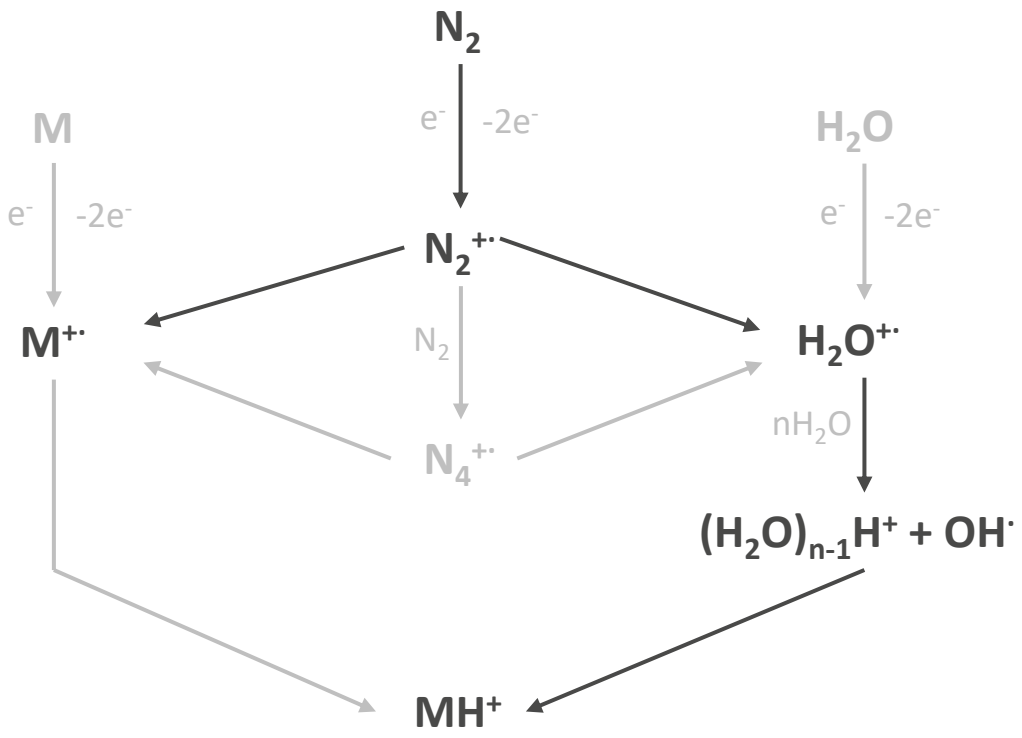


SICRIT® Ionization Mechanism:

- Discharge forms excited carrier gas species e.g. N_2^+
- Those may interact with water and form hydronium clusters
- Hydronium clusters can also be formed directly in the discharge
- Finally hydronium clusters will protonate the analyte

Three simultaneous ionization mechanisms expand the range of detectable analytes (2/3)

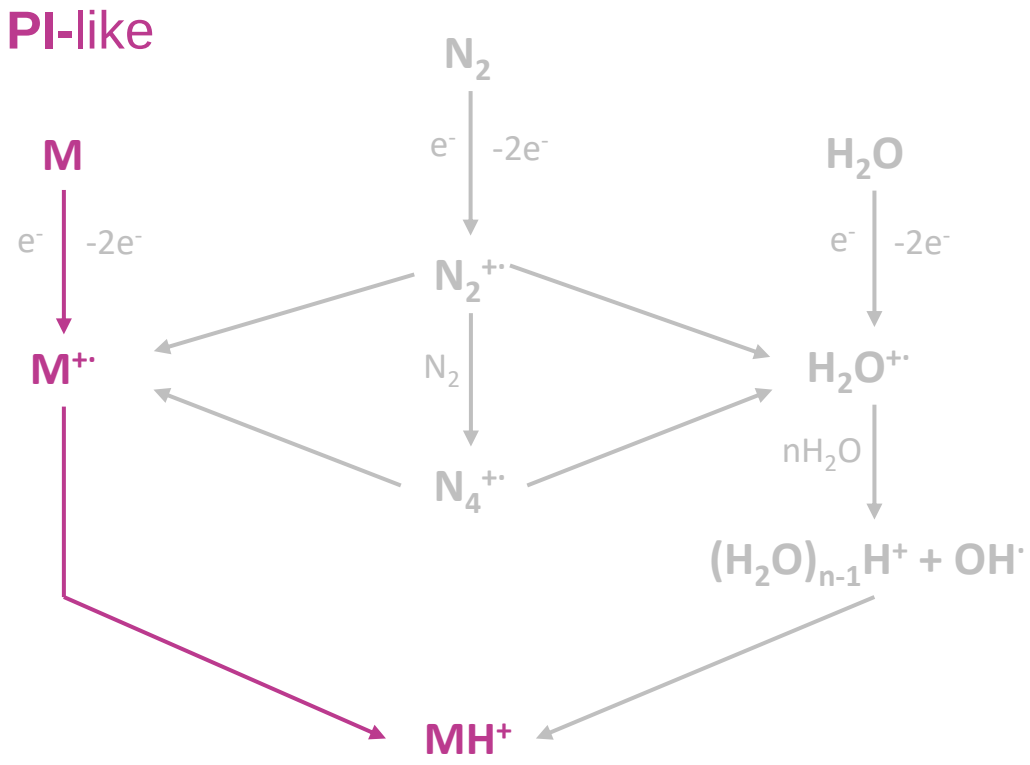
APCI-like



SICRIT® Ionization Mechanism:

- Discharge forms excited carrier gas species e.g. N_2^+
- Those may interact with water and form hydronium clusters
- Hydronium clusters will protonate the analyte
- Reactive species may directly interact with the analyte and form cations

Three simultaneous ionization mechanisms expand the range of detectable analytes (3/3)

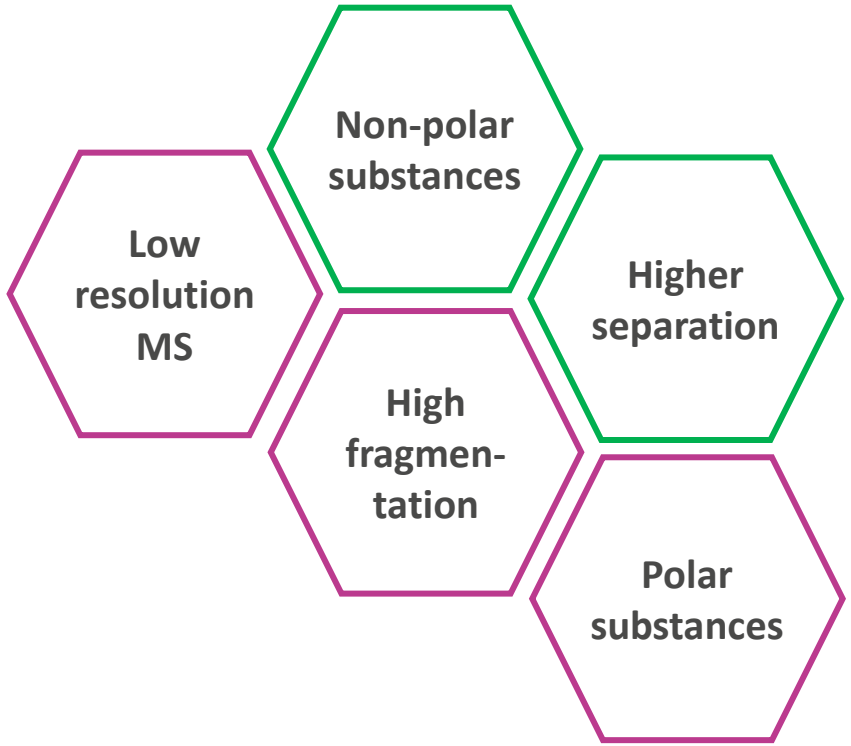


SICRIT® Ionization Mechanism:

- Discharge emits highly energetic UV light that can ionize the molecule directly or via charge transfer
- Depending on the ion's chemistry, the radical cation may fragment, stabilize by hydrid abstraction or prevail

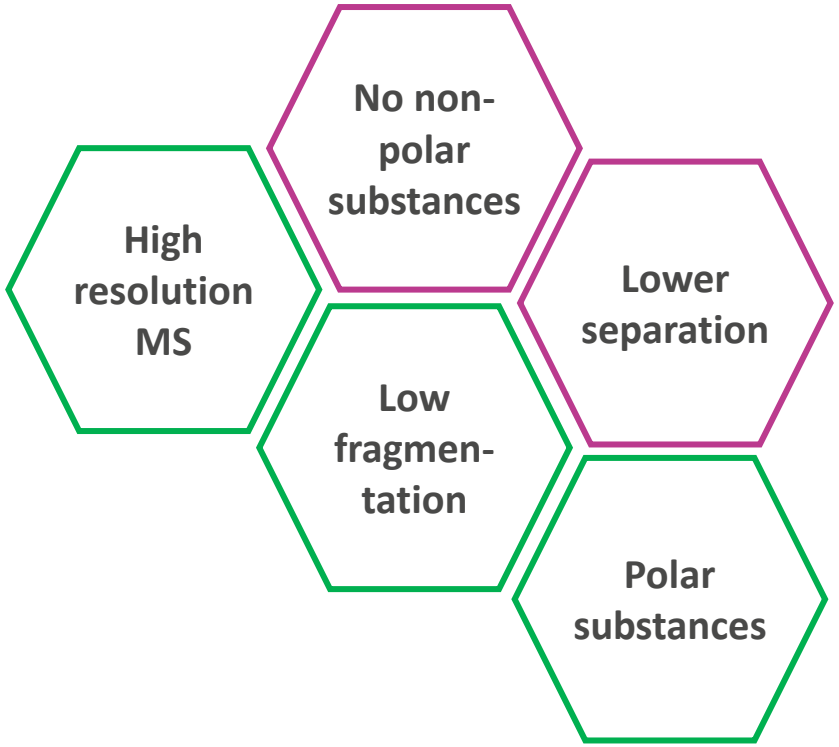
GC-MS and LC-MS represent two different worlds, with each having its own dis-/advantages

GC-Mass Spectrometry (MS)



VS.

LC-Mass Spectrometry (MS)



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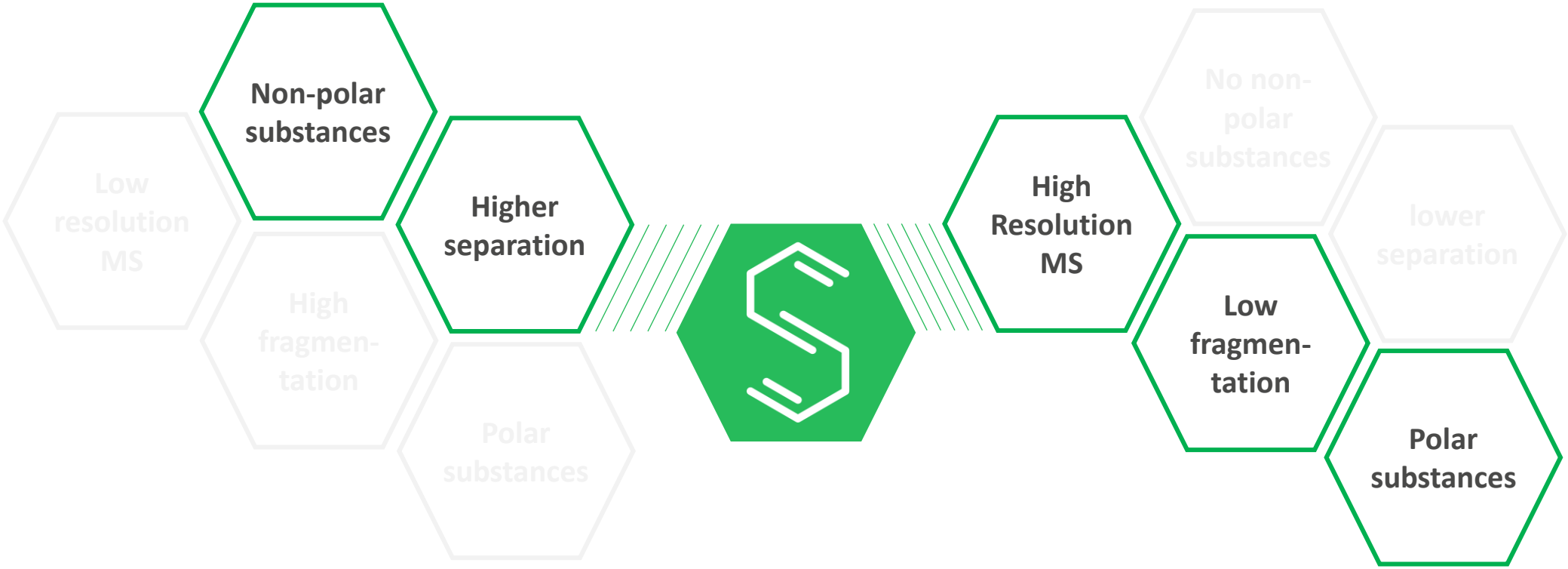
Disadvantages Advantages

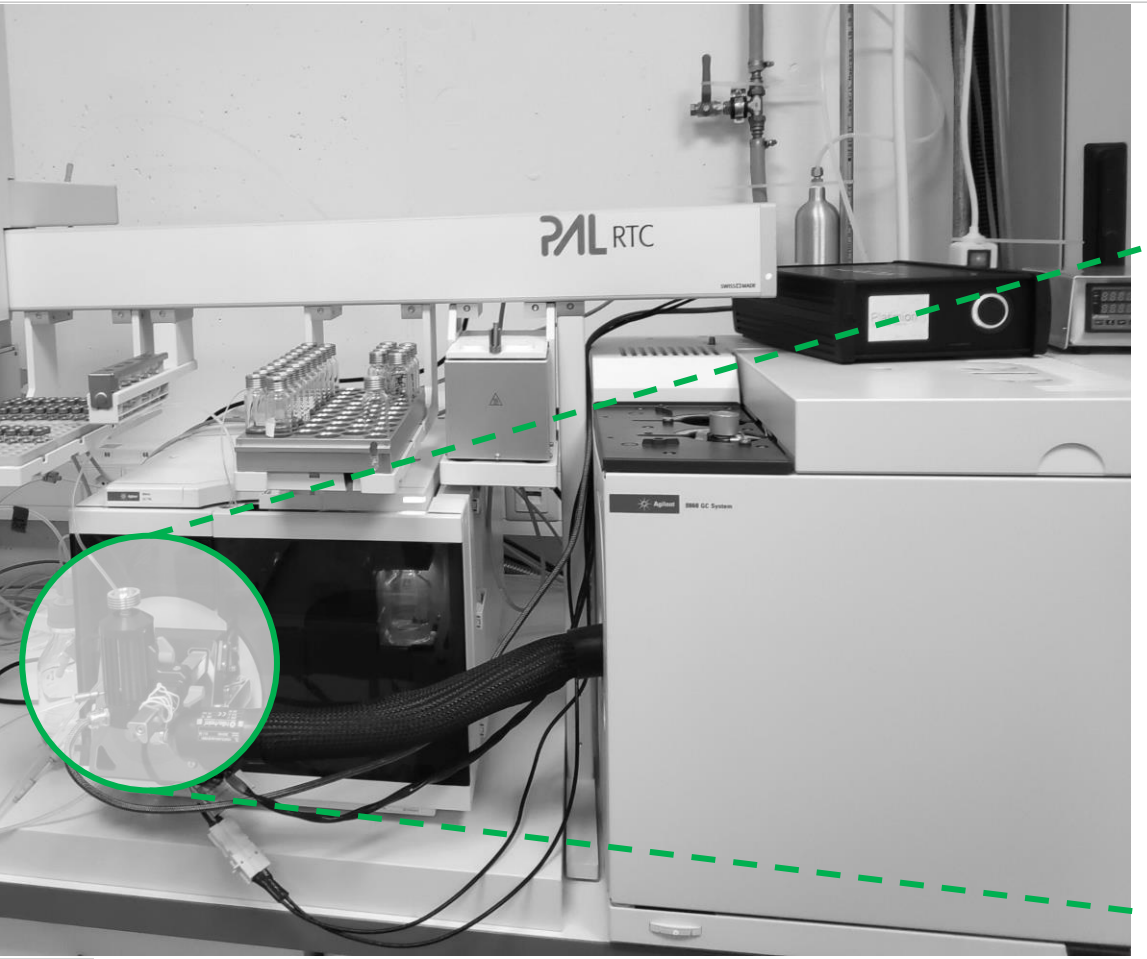
SICRIT® provides a link between both worlds which enables to combine all advantages in one solution

SICRIT®-GC-Mass Spectrometry (MS)

Advantages Disadvantages



Via its GC-SPME-Module, SICRIT® allows for a fast and easy coupling between LC-MS and GC



The SICRIT® technology can be coupled with almost every LC-MS* of all major vendors

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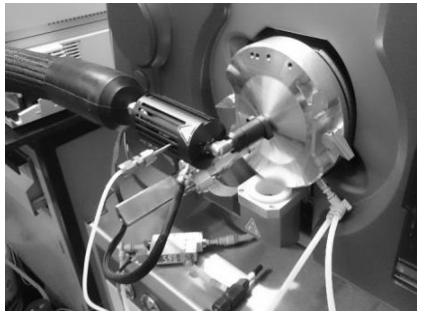
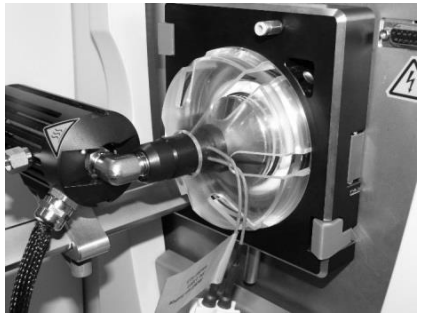
BRUKER

SHIMADZU

Agilent-SICRIT-Coupling



Sciex-SICRIT-Coupling



Thermo-SICRIT-Coupling

Picture coming soon

Waters-SICRIT-Coupling

Picture coming soon

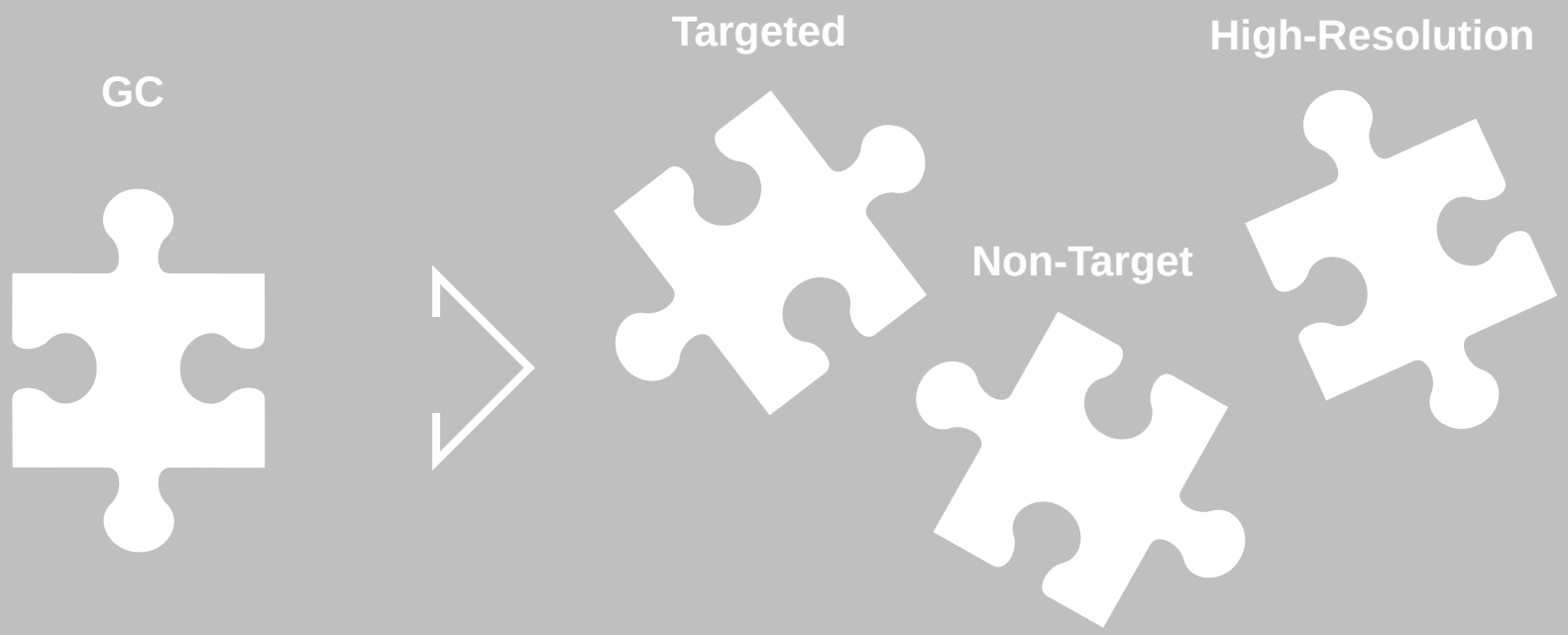
Bruker-SICRIT-Coupling

Picture coming soon

Shimadzu-SICRIT-Coupling

* Couplings to specific LC-MS systems that are not yet available can be provided upon request

SICRIT® enables to flexibly combine the most suitable instruments for your application – vendor independent



- Easily **combine** instruments of different **vendors**
- **Choose** instrument **performance according to** your application **needs**
- **Save money** and laboratory space due to SICRIT® technology that serves as generic interface

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SICRIT® enables various applications across routine and advanced research analyses

1 Routine Analyses

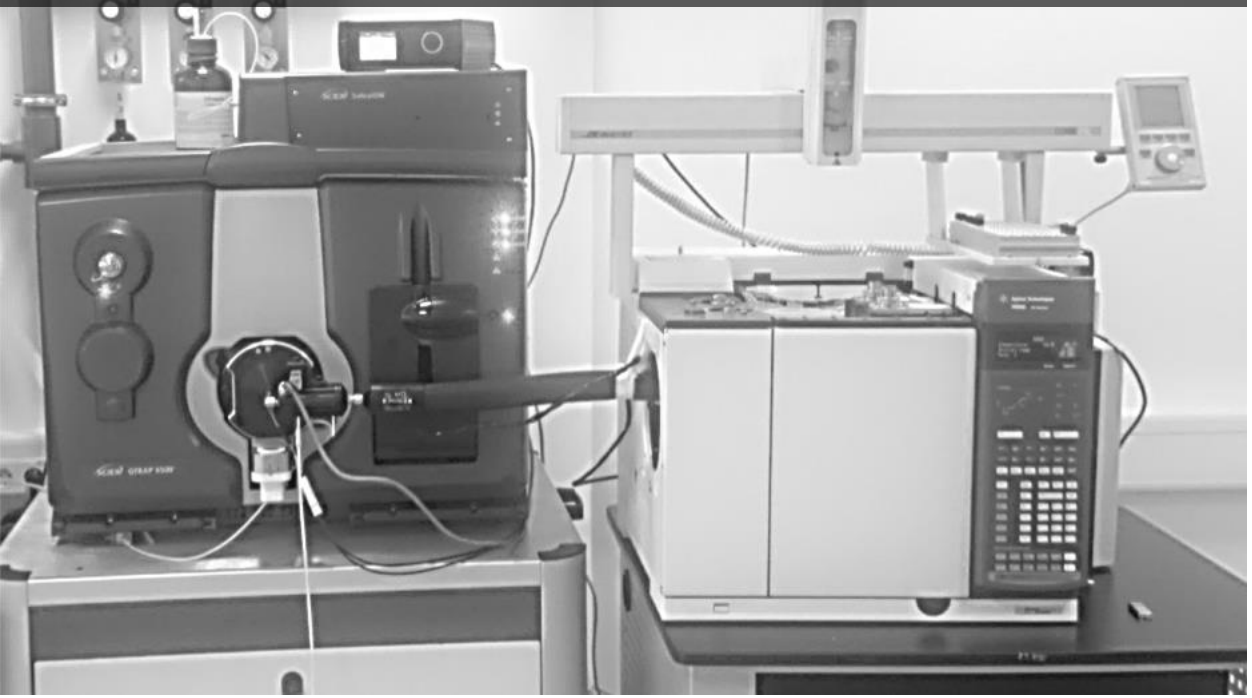
- In **routine** analyses, most frequently the focus is on **searching for certain analytes** and thus to perform a targeted high sensitivity analysis. To do so, a **Triple-Quad-MS** is mostly the preferred option.
- However, there are also **some cases**, where **High-Resolution-MS** are introduced to perform routine analysis. In fact, High-Resolution-MS is gaining more and more attention

2 Advanced Research Analyses

- In **research analyses**, it is often not one specific application that is to be performed with a respective MS system. The **range of applications** may go **from targeted to** completely **untargeted** search for analytes. Thus, not only high sensitivity but also **high resolution** is **important**, to enable a rigor identification of the respective analytes

1 GC-SICRIT®-MS applied for known tasks in routine pesticide analyses

Setup:
GC-MS coupling with SICRIT® and SCIEX 6500 Q-Trap; Agilent 7890 GC with PAL autosampler; He as carrier gas, Splitless 1 µl injection; DB5-MS column; individually optimized MRMs



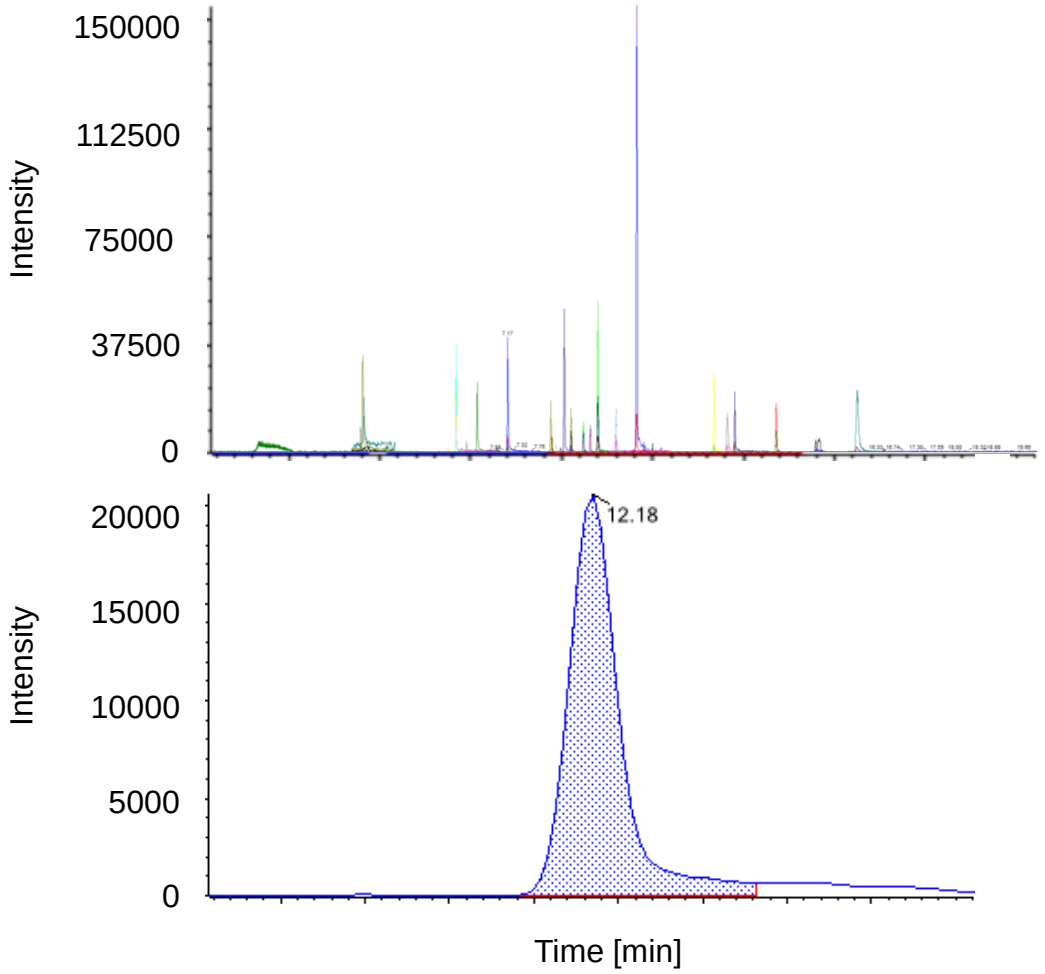
List of measured pesticides:

Substance	Sum Form.
2,4-D-isobutylester	$C_{12}H_{14}Cl_2O_3$
3-decen-2-one	$C_{10}H_{18}O$
Acetamiprid	$C_{10}H_{11}ClN_4$
Atrazine	$C_8H_{14}ClN_5$
Azoxystrobin	$C_{22}H_{17}N_3O_5$
Beflubutamid	$C_{18}H_{17}F_4NO_2$
Chlorpyrifos	$C_9H_{11}Cl_3NO_3PS$
Chlorpyrifos-methyl	$C_7H_7Cl_3NO_3PS$
Cypermethrin	$C_{22}H_{19}Cl_2NO_3$
DDE-PP	$C_{14}H_8Cl_4$
Deltamethrin (cis)	$C_{22}H_{19}Br_2NO_3$
Demeton-S-methyl	$C_6H_{15}O_3PS_2$
Dichlobenil	$C_7H_3Cl_2N$
Dichlorvos	$C_4H_7Cl_2O_4P$
Simeconazole	$C_{14}H_{20}FN_3OSi$
Vinclozolin	$C_{12}H_9Cl_2NO_3$

Substance	Sum Form.
Dieldrin	$C_{12}H_8Cl_6O$
Diflufenican	$C_{19}H_{11}F_5N_2O_2$
DMSA	$C_4H_6O_4S_2$
EPN	$C_{14}H_{14}NO_4PS$
Flurprimidol	$C_{15}H_{15}F_3N_2O_2$
Genite	$C_{12}H_8Cl_2O_3S$
Hexaconazole	$C_{14}H_{17}Cl_2N_3O$
Methamidophos	$C_2H_8NO_2PS$
Myclobutanil	$C_{15}H_{17}ClN_4$
Omethoate	$C_5H_{12}NO_4PS$
Pirimiphos-ethyl	$C_{13}H_{24}N_3O_3PS$
Pirimiphos-methyl	$C_{11}H_{20}N_3O_3PS$
Pyrazophos	$C_{14}H_{20}N_3O_5PS$
Quinalphos	$C_{12}H_{15}N_2O_3PS$
Triadimefon	$C_{14}H_{16}ClN_3O_2$

1 Good s/n-values and peak shape for most pesticides even at low concentration levels

Component	S/N-Values
2,4-D-isobutylester	5
3-decen-2-one	188.4
Acetamiprid	314.5
Atrazine	482.3
Azoxystrobin	455.2
Beflubutamid	2874.6
Chlorpyrifos	719.5
Chlorpyrifos-methyl	352.7
Cypermethrin(sum)	205.6
DDE-PP	25.9
Deltamethrin	112.2
Demeton-S-methyl	66.5
Dichlobenil	46.3
Dichlorvos	89.3
Dieldrin	508.7
Diflufenican	825.7
DMSA	761.7
EPN	422.2
Flurprimidol	283.7
Genite	16.8
Hexaconazole	65.6
Methamidophos	146.7
Myclobutanil	391.6
Omethoate	703.1
Pirimiphos-ethyl	570.2
Pirimiphos-methyl	332.3
Pyrazophos	729.8
Quinalphos	172
Simeconazole	129.4
Triadimefon	257.1
Vinclozolin	2.4



Signal Intensity

Results showed **good** signal intensity for the SICRIT-GC-MS coupling **for 1 pg on column**

Peak Shape

Results showed **good** peak shape for the SICRIT-GC-MS coupling **for 1 pg on column**

1 Direct comparison shows that GC-SICRIT®-MS is more sensitive for most pesticides than GC-APCI

Comparison Setup

- **Comparison of S/N ratio** between GC-SICRIT®-MS and GC-APCI –

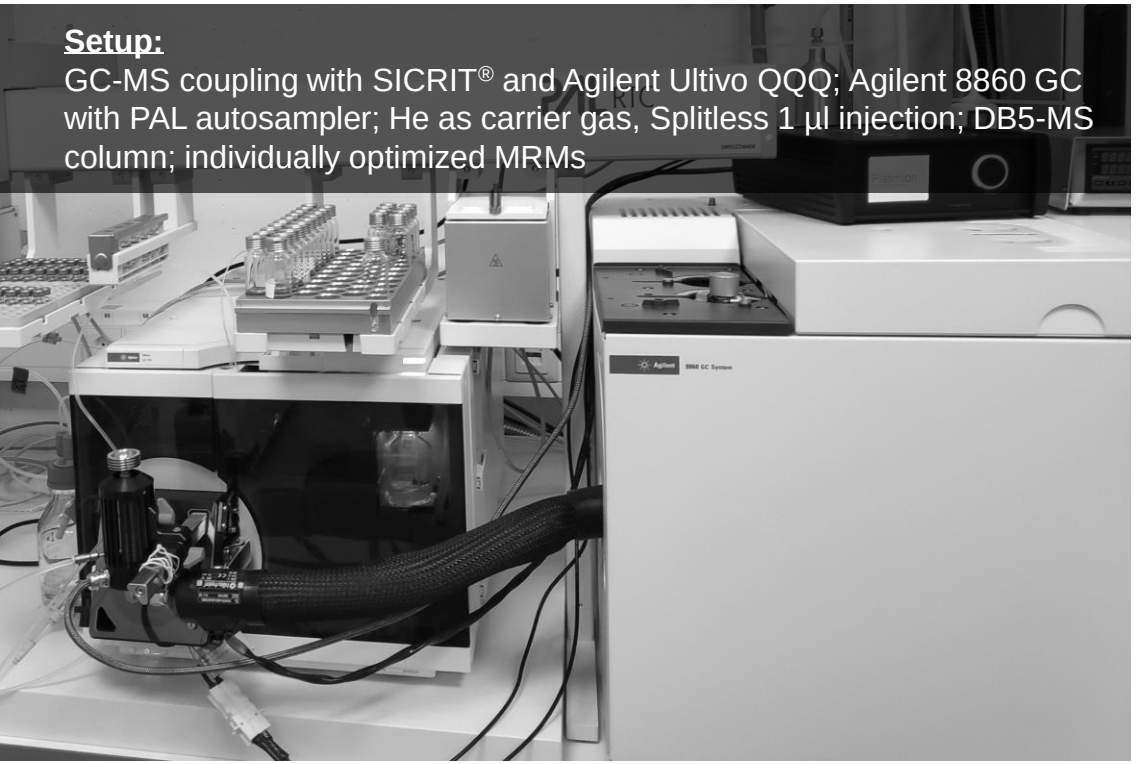
  S/N ratios are usually not fully comparable, but show a general trend

- Data **measured on two comparable Triple-Q systems** of different manufacturers (SICRIT® on SCIEX 6500+ QTRAP vs. competitor)

- Both systems with **1 pg on column**

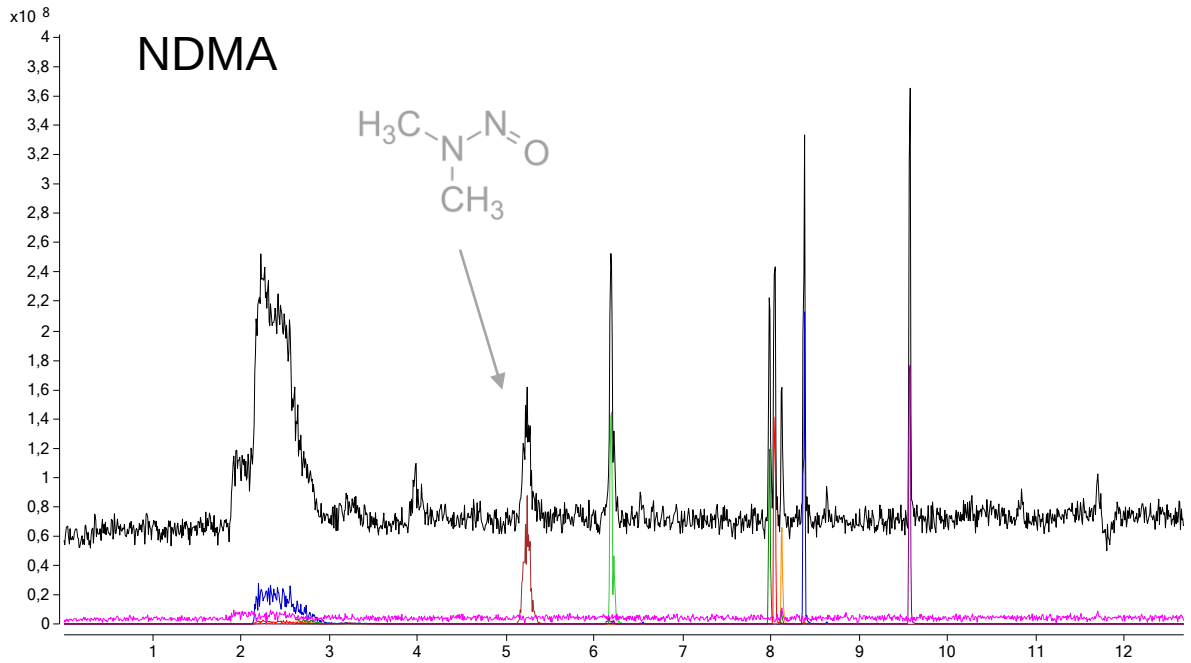
Component	GC-SICRIT-MS	GC-APCI-MS
2,4-D-isobutylester	5	5.9
3-decen-2-one	188.4	-
Acetamiprid	314.5	2.9
Atrazine	482.3	19.6
Azoxystrobin	455.2	97.5
Beflubutamid	2874.6	2.2
Chlorpyrifos	719.5	9.5
Chlorpyrifos-methyl	352.7	53.1
Cypermethrin(sum)	205.6	41.9
DDE-PP	25.9	43.4
Deltamethrin	112.2	21.7
Demeton-S-methyl	66.5	9.9
Dichlobenil	46.3	28.9
Dichlorvos	89.3	163.8
Dieldrin	508.7	9.5
Diflufenican	825.7	242.9
DMSA	761.7	19.4
EPN	422.2	32.9
Flurprimidol	283.7	308.5
Genite	16.8	48.1
Hexaconazole	65.6	12.8
Methamidophos	146.7	3558
Myclobutanil	391.6	111.2
Omethoate	703.1	31.2
Pirimiphos-ethyl	570.2	16.5
Pirimiphos-methyl	332.3	94.7
Pyrazophos	729.8	66.9
Quinalphos	172	12983.6
Simeconazole	129.4	22361.8
Triadimefon	257.1	7.9
Vinclozolin	2.4	1.4

1 Analysis of Nitrosamines: a substance class of pharmaceutical concern



Setup:
GC-MS coupling with SICRIT® and Agilent Ultivo QQQ; Agilent 8860 GC with PAL autosampler; He as carrier gas, Splitless 1 µl injection; DB5-MS column; individually optimized MRMs

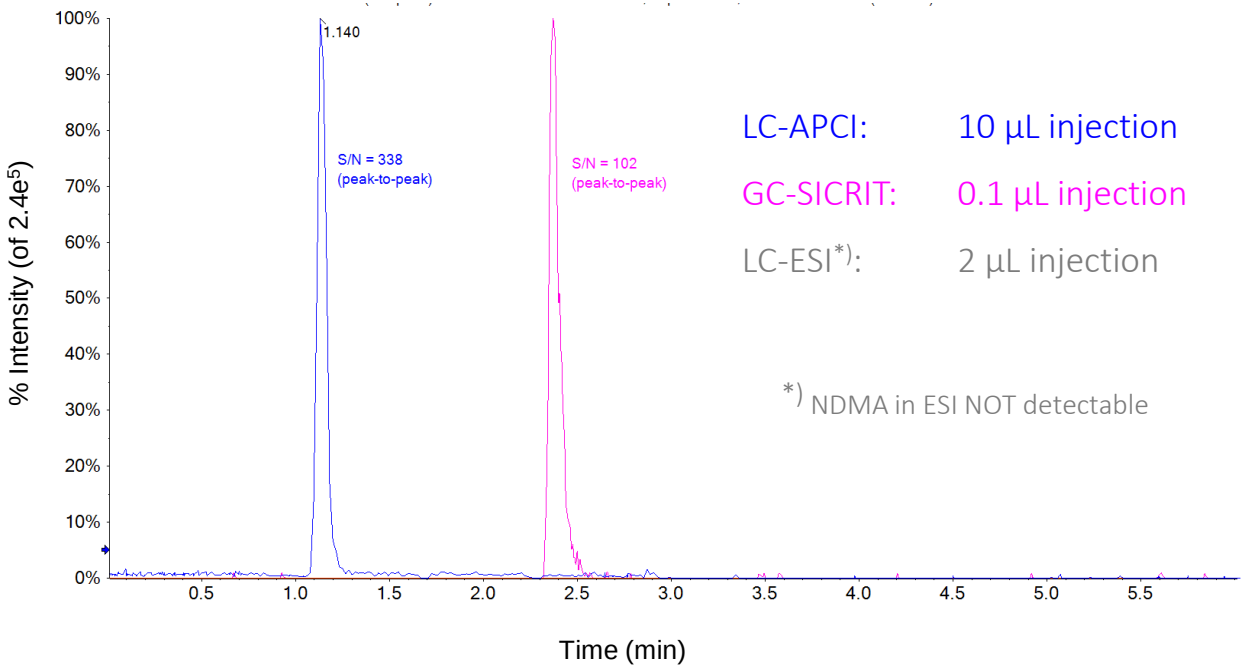
Chromatogram of EPA 521 Nitrosamine standard



Counts vs. Acquisition Time (min)

1 In contrast to LC-ESI/APCI, GC-SICRIT® can detect both Valsartan and Nitrosamines

Comparison of LC-MS vs GC-SICRIT-MS (SCIEX X500R)



LC-APCI: 10 µL injection

GC-SICRIT: 0.1 µL injection

LC-ESI*): 2 µL injection

*) NDMA in ESI NOT detectable

LODs for Nitrosamines (Ultivo QQQ)*

Substance	LOD (fg)
N-Nitrosodimethylamine	1205
N-Nitrosodibutylamine	91
N-Nitrosodi-*n*-propylamine	139
N-Nitrosomethylethylamine	379
N-Nitrosodiethylamine	69
1-Nitrosopyrrolidine	376
1-Nitrosopiperidine	540

* Individual quan- and qualifier MRMs; LOD calculated according to 3σ blank; lowest calibration point 200 fg

Conclusion

- **GC-SICRIT®-MS** is **perfectly suited for** routine **Nitrosamines** measurement
- **~30x more sensitive than LC-APCI** on the same instrument (X500R)
- **Can** also **detect** active ingredient **"Valsartan"** which is **not detected via APCI**
- **QQQ** method reveals **LODs** in the **ppt range**

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1 SICRIT can even be used to detect perchlorinated pesticides

Setup:
GC-MS coupling with SICRIT and Orbitrap LTQ XL; UltraTrace GC autosampler; He as carrier gas; Splitless 1 µl injection; DB5-MS column

List of measured pesticides:

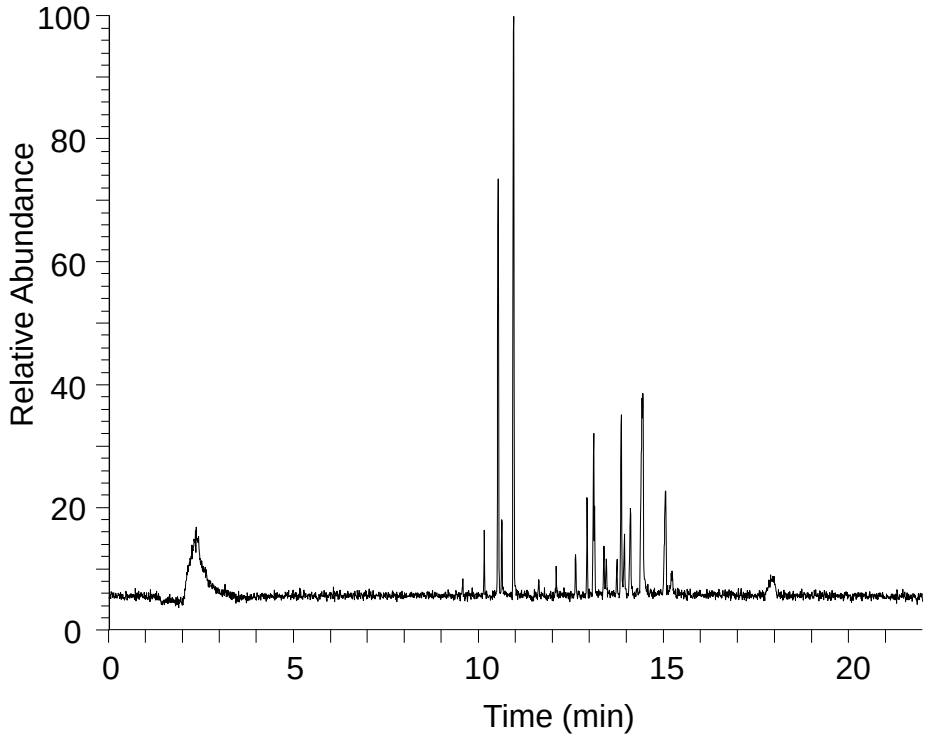
Substance	Sum Form.
2,4,5,6-Tetrachloroxylene	$C_8H_6Cl_4$
alpha-BHC	$C_6H_6Cl_6$
gamma-BHC	$C_6H_6Cl_6$
beta-BHC	$C_6H_6Cl_6$
delta-BHC	$C_6H_6Cl_6$
Heptachlor	$C_{10}H_5Cl_7$
Aldrin	$C_{12}H_8Cl_6$
Heptachlor epoxide	$C_{10}H_5Cl_7O$
gamma-Chlordane	$C_{10}H_6Cl_8$
alpha-Chlordane	$C_{10}H_6Cl_8$
Endosulfan1	$C_9H_6Cl_6O_3S$

Substance	Sum Form.
4,4-DDD	$C_{14}H_{10}Cl_4$
Endosulfan2	$C_9H_6Cl_6O_3S$
Endrin aldehyde	$C_{12}H_8Cl_6O$
4,4-DDT	$C_{14}H_9Cl_5$
Endosulfan sulfate	$C_9H_6Cl_6O_4S$
Methoxychlor	$C_{16}H_{15}Cl_3O_2$
Endrin keton	$C_{12}H_8Cl_6O$
Decachlorobiphenyl	$C_{12}Cl_{10}$
4,4-DDE	$C_{14}H_8Cl_4$
Dieldrin	$C_{12}H_8Cl_6O$
Endrin	$C_{12}H_8Cl_6O$

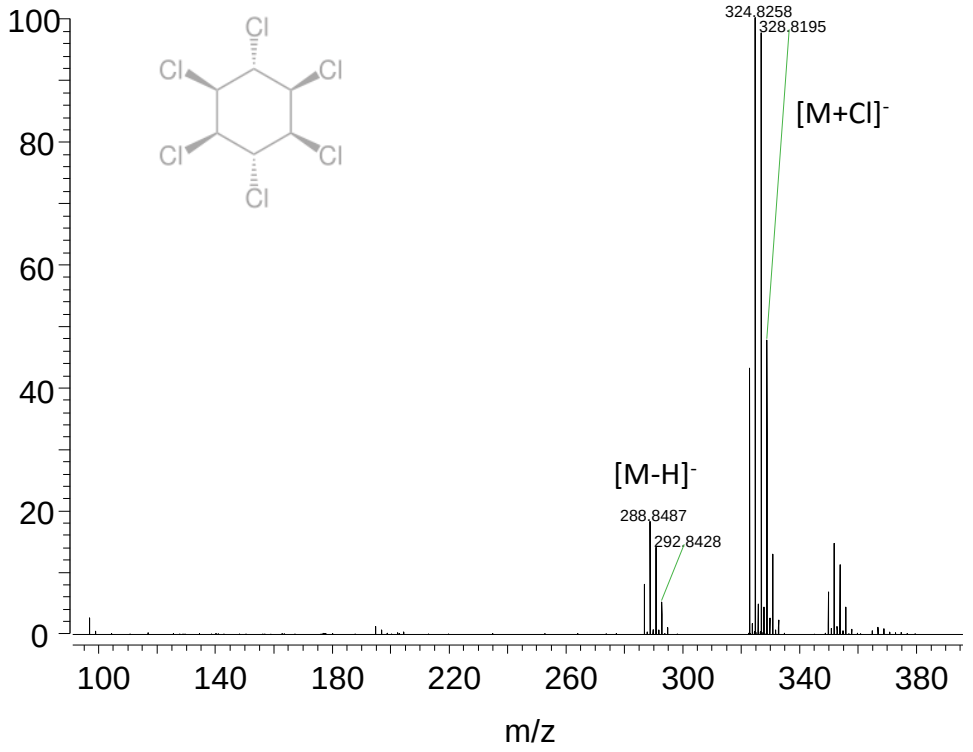
A classic example for GC-MS analytics are heavily chlorinated pesticides. These group of molecules cannot be ionized by LC-MS.

1 First results show that SICRIT® is capable to ionize perchlorinated compounds

GC-Separation of EPA 8081 with standard GC-Program



MS-Spectrum of γ-Lindane

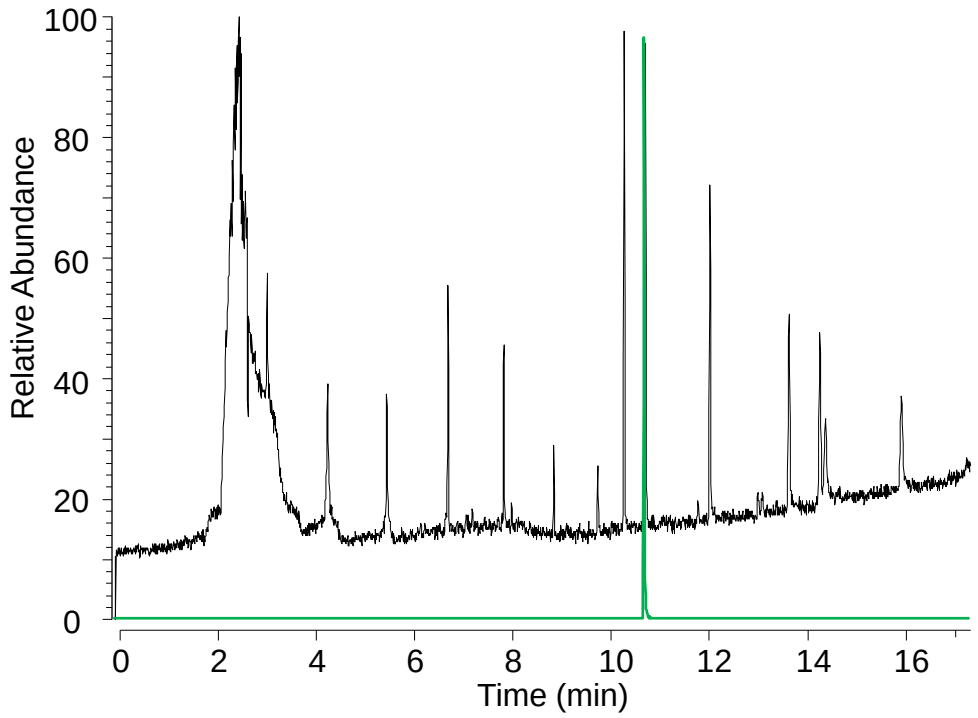


Conclusion

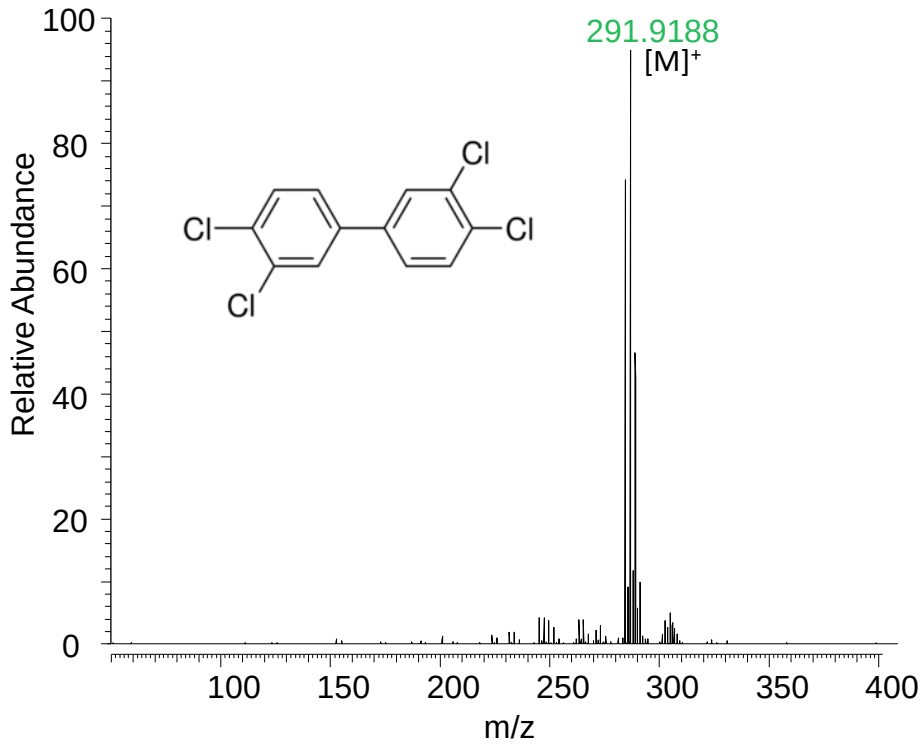
- First analysis show that **SICRIT enables analysis** of **perchlorinated pesticides** in negative ion mode
- It delivers molecular ions/adducts for all perchlorinated pesticides with (almost) **no fragmentation**
- It moreover not only enables detection but also **quantification**
- However, the application still **needs more** evaluation and **optimization**

1 SICRIT® is capable to ionize PCBs efficiently in positive mode

GC-Separation of PCB-Mix with standard GC-Program



MS-Spectrum of PCB 77



Conclusion

- **SICRIT enables analysis** of **PCBs** in positive ion mode
- It delivers molecular ions for all PCBs with no **fragmentation**
- First results show LODs < 5 pg on LTQ Orbitrap full scan mode
- Dry carrier gas is beneficial for analysis of chlorinated compounds

SICRIT® enables various applications across routine and advanced research analyses

1 Routine Analyses

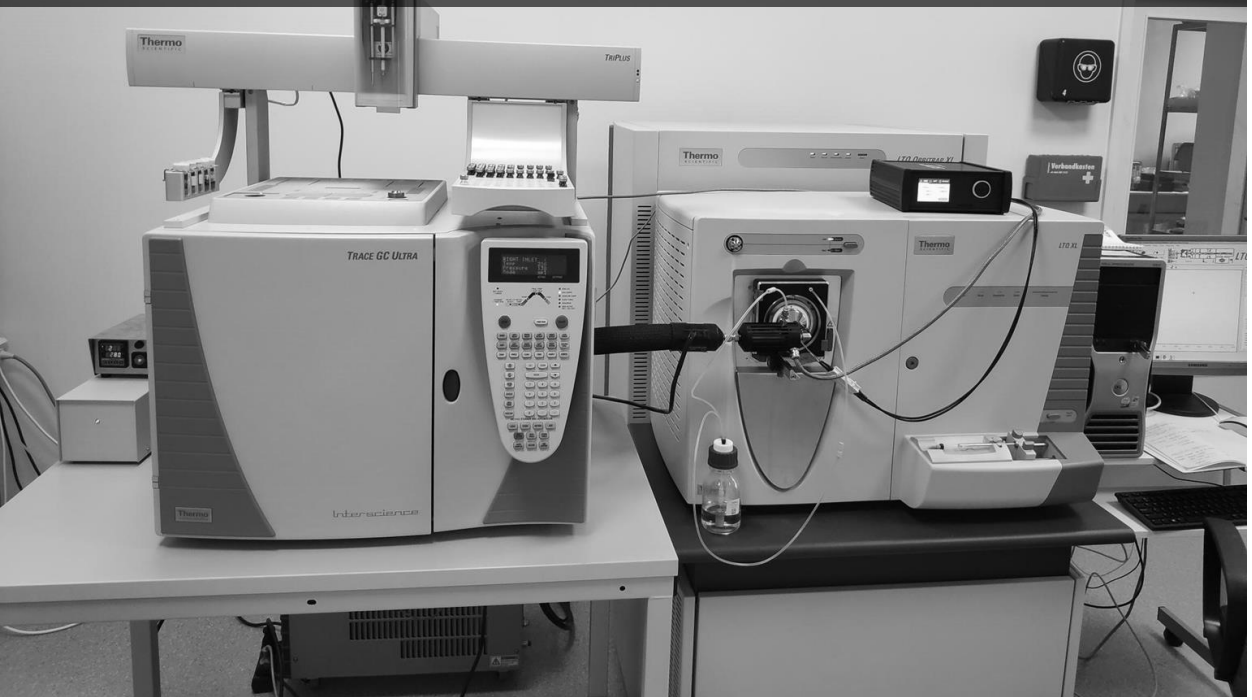
- In **routine** analyses, most frequently the focus is on **searching for certain analytes** and thus to perform a targeted high sensitivity analysis. To do so, a **Triple-Quad-MS** is mostly the preferred option.
- However, there are also **some cases**, where **High-Resolution-MS** are just to perform routine analysis. In fact, High-Resolution-MS is gaining more and more attention

2 Advanced Research Analyses

- In **research analyses**, it is often not one specific application that is to be performed with a respective MS system. The **range of applications** may go **from targeted to** completely **untargeted** search for analytes. Thus, not only high sensitivity but also **high resolution** is **important**, to enable a rigor identification of the respective analytes

2 GC-SICRIT-HRMS enables to individually quantify n-Alkanes and perform structural elucidation

Setup:
GC-Orbitrap-MS coupling with SICRIT; He as carrier gas; Alkane mix; 1 µL inject; DB5-MS column; Full MS-Scan; Quantified on accurate MH+ (2 ppm window)



List of measured n-Alkanes:

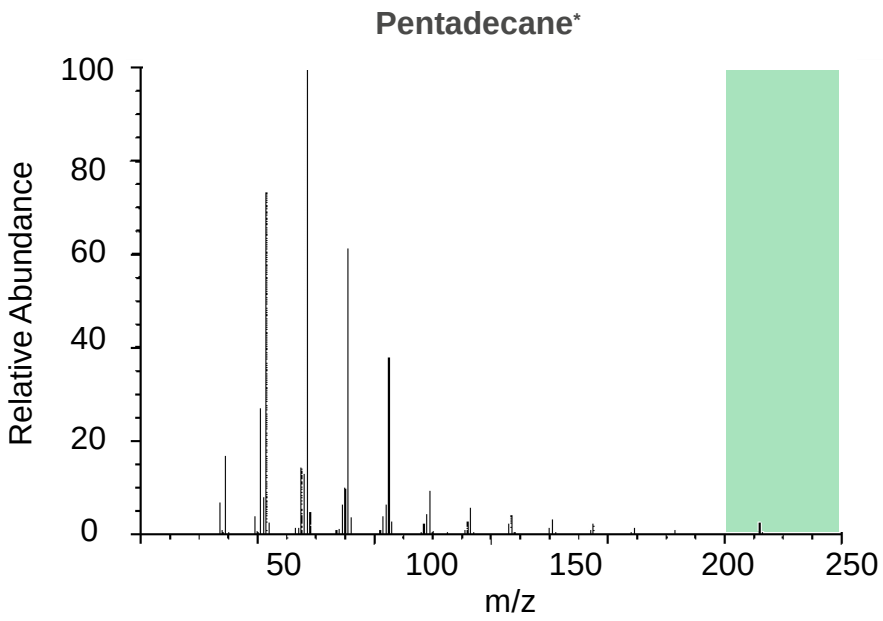
Substance	Sum Form.
n-octane	C_8H_{18}
n-nonane	C_9H_{20}
n-decane	$C_{10}H_{22}$
n-undecane	$C_{11}H_{24}$
n-dodecane	$C_{12}H_{26}$
n-tridecane	$C_{13}H_{28}$
n-tetradecane	$C_{14}H_{30}$
n-pentadecane	$C_{15}H_{32}$
n-hexadecane	$C_{16}H_{34}$
n-heptadecane	$C_{17}H_{36}$
n-octadecane	$C_{18}H_{38}$
n-nonadecane	$C_{19}H_{40}$
n-eicosane	$C_{20}H_{42}$

Saturated hydrocarbons (**Alkanes**) play an **important role in** environmental and food **analytics**. **Analysis** is a demanding and **still not standardized** task in analytical chemistry.

2 Compared to existing methods, it enables to identify molecular ions for n-Alkanes

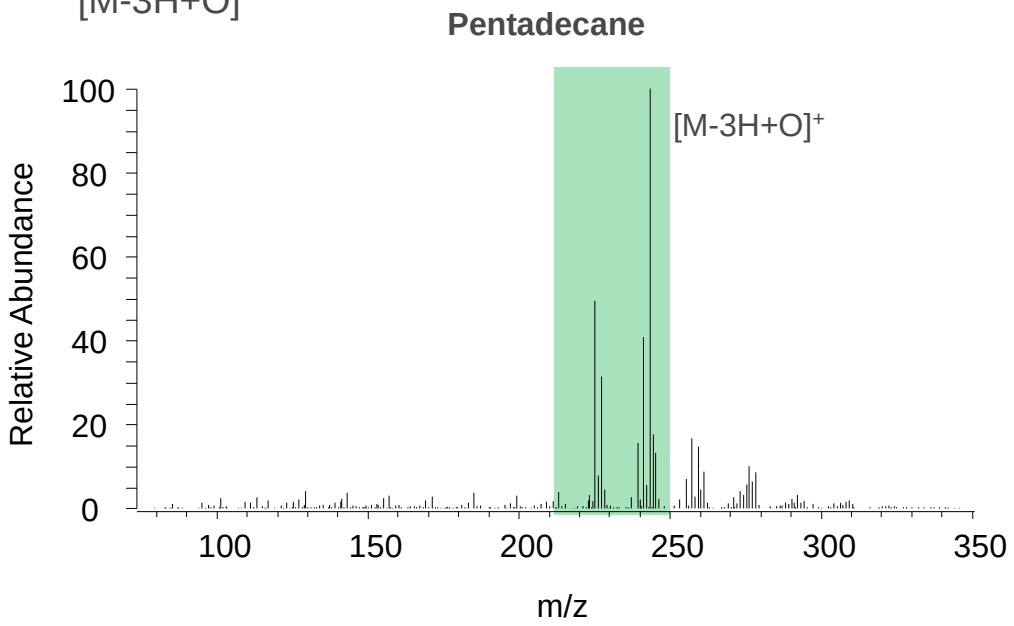
Status Quo LC/GC-MS

- **LC-MS** is **not capable** to detect n-Alkanes
- **GC-MS** is **capable** to detect them. **However**, due to electronic impact ionization used in GC-MS, the molecular **ions get fragmented** and thus the interpretation of the results is difficult to almost impossible



GC-SICRIT®-HRMS

- **GC-SICRIT®-HRMS** is not only **capable** to detect n-Alkanes, but due to its soft ionization mechanism, it moreover delivers (quasi) **molecular n-Alkane ions** and little to **no fragmentation**. This **allows** the **determination of** the **alkane chain length** by molecular adduct peak for alkanes $[M-3H+O]^+$

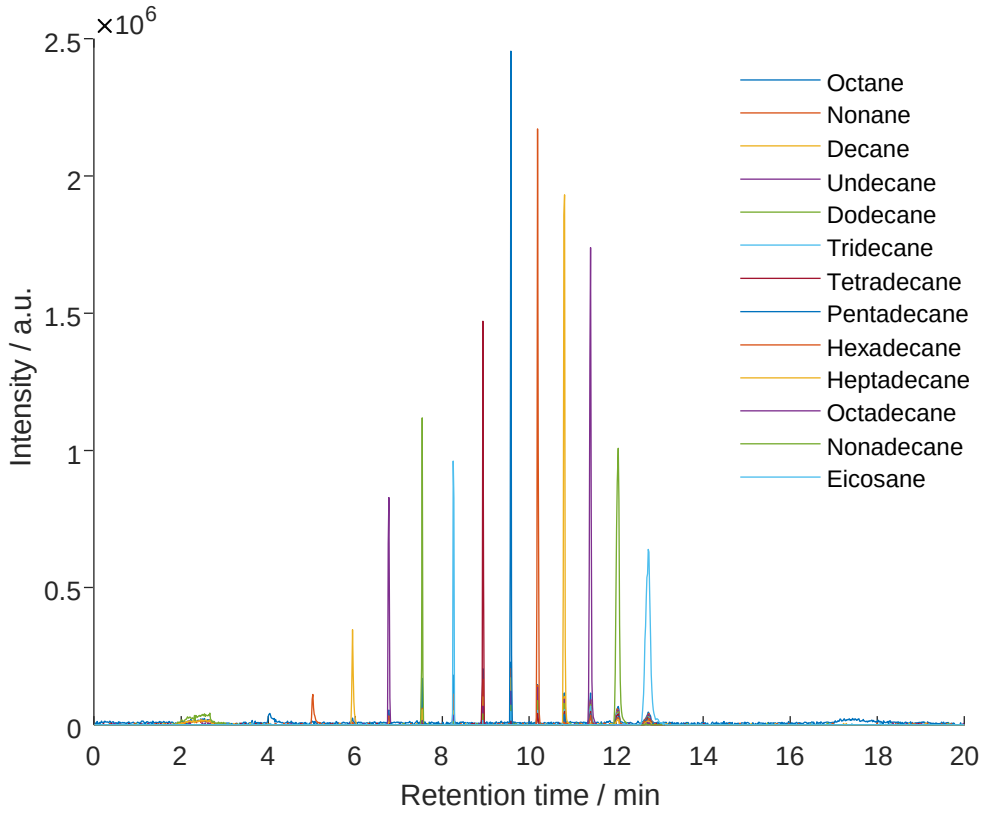


Plasmion simple smart sensitive

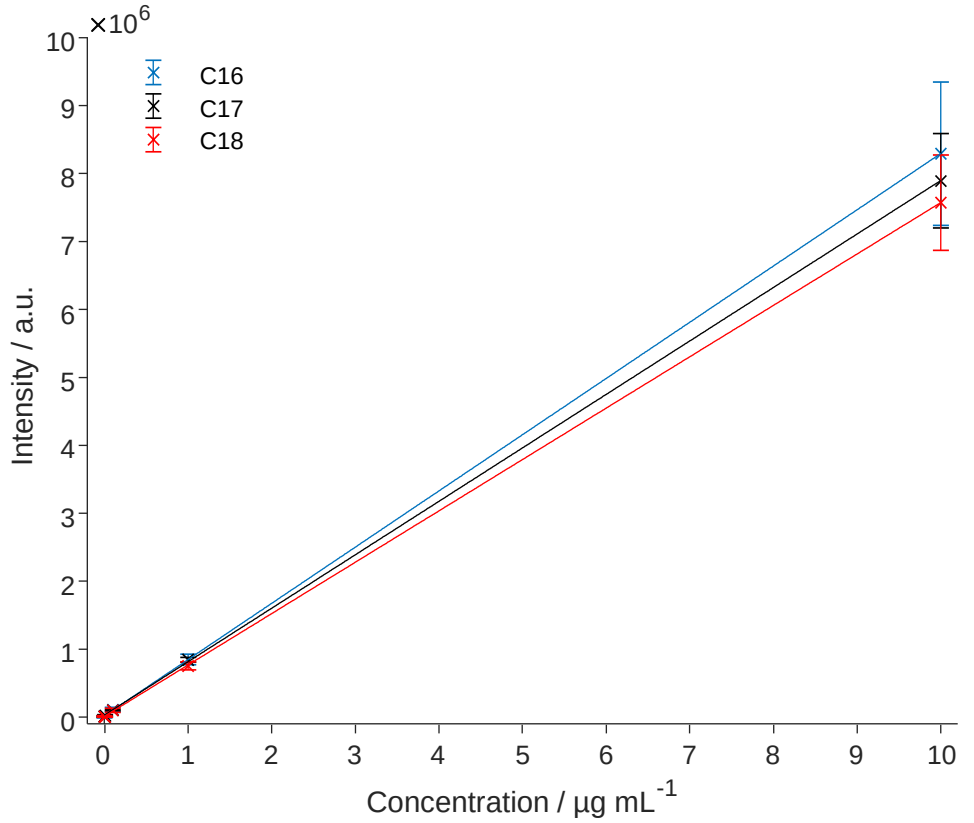
*NIST Chemistry Webbook: https/webbook.nist.gov/chemistry

2 GC-SICRIT® HRMS moreover enables a sensitive and reliable quantification of n-Alkanes

Extracted ion chromatograms across n-Alkanes



Exemplary calibration curves for C16-C18

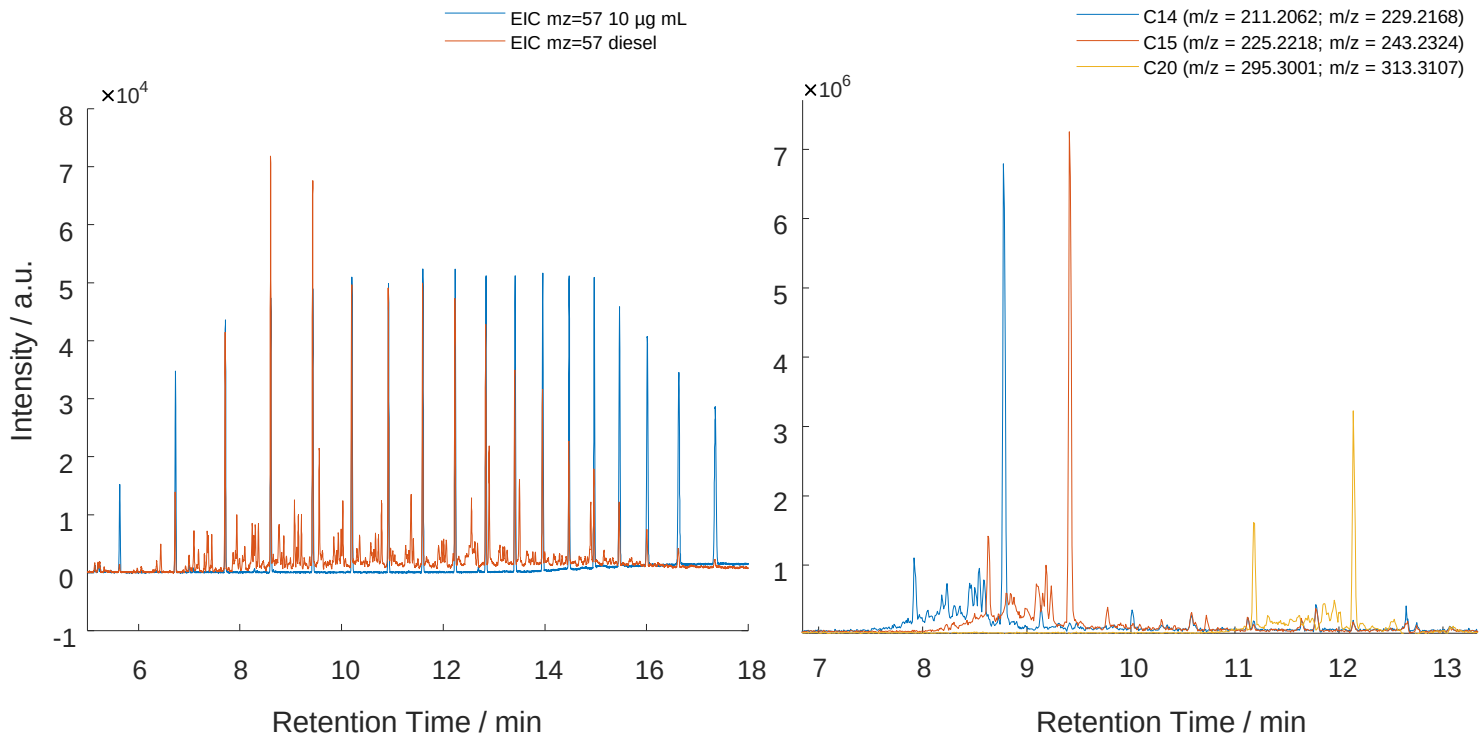


2 Compared to EI, SICRIT® identifies specific n-Alkanes and provides a similar analysis result

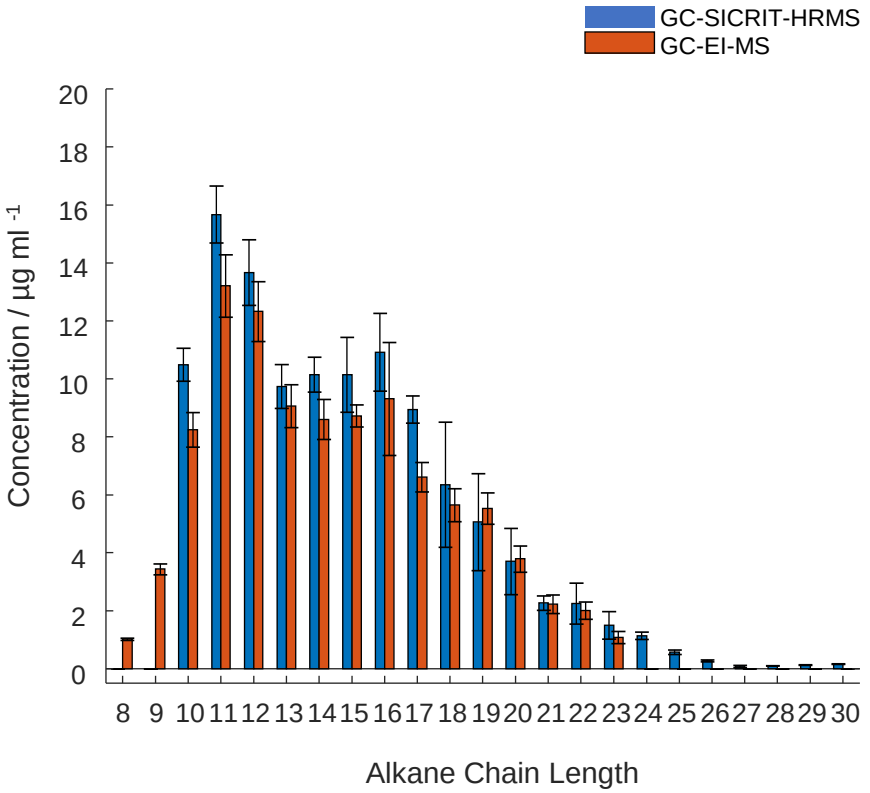
n-Alkanes with EI

vs.

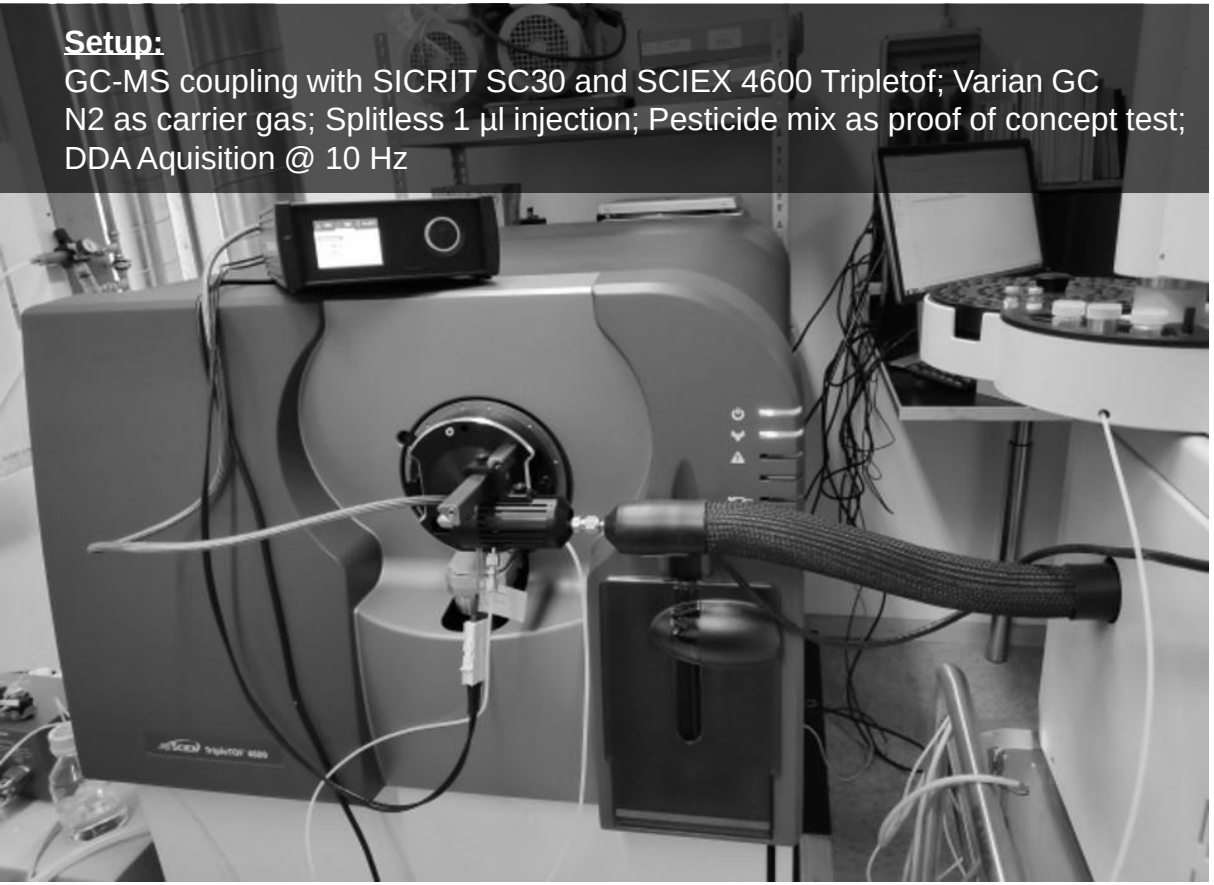
n-Alkanes with SICRIT®



EI and SICRIT® show similar analysis results



2 GC-SICRIT®-HRMS applied to identify analytes in a completely unknown sample – non-target



Setup:
GC-MS coupling with SICRIT SC30 and SCIEX 4600 Tripletof; Varian GC
N2 as carrier gas; Splitless 1 µl injection; Pesticide mix as proof of concept test;
DDA Aquisition @ 10 Hz

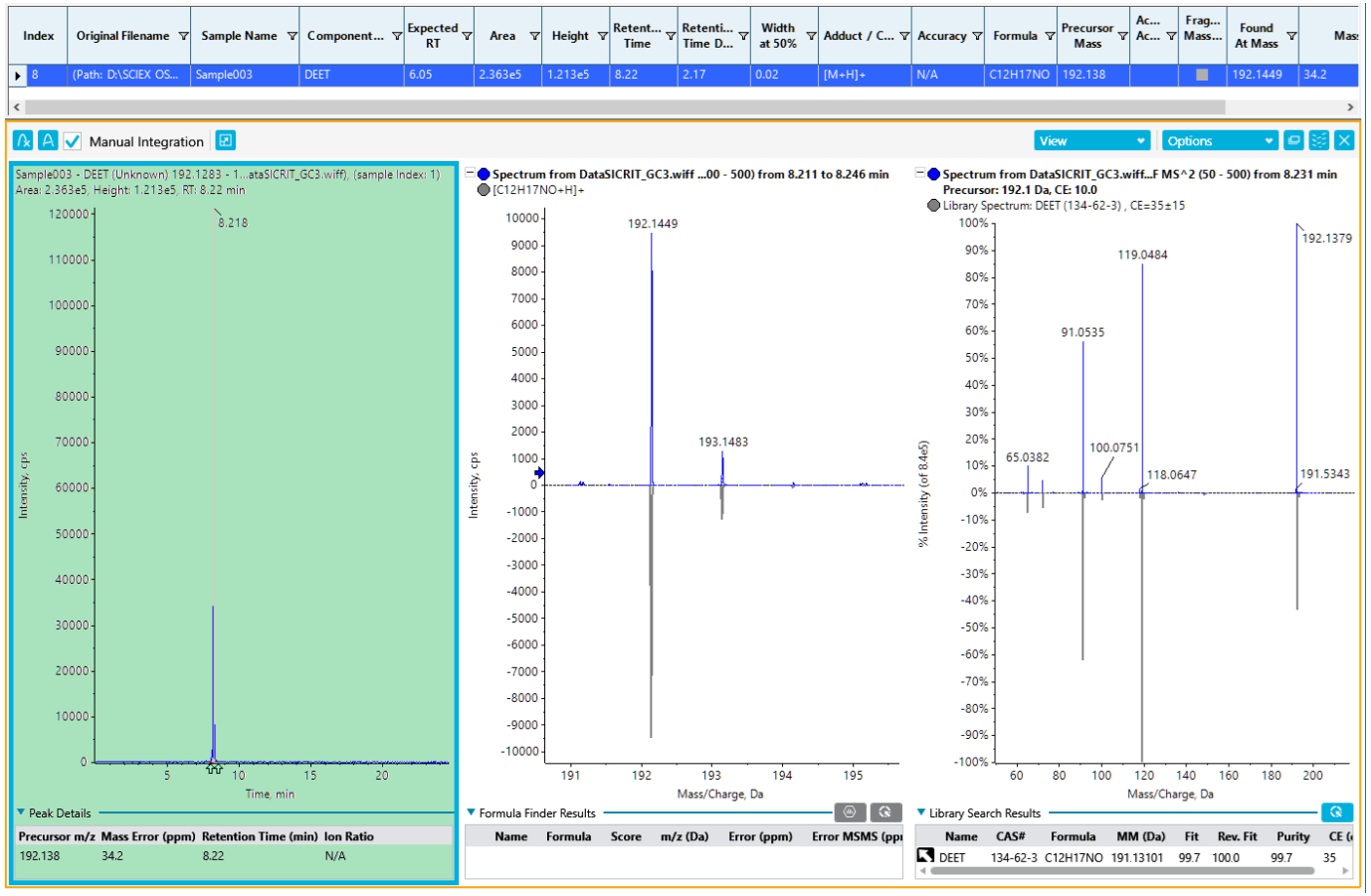
Objective

- GC-SICRIT®-HRMS used to **identify all components** or rather analytes in a completely **unknown sample**
- Non-Target Screening carried out in cooperation with AFIN-TS GmbH and by **leveraging SCIEX LC-MS Database**

In cooperation with:

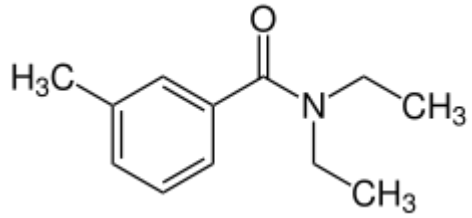
AFIN -TS

2 Automated identification after GC-SICRIT®-MS run due to LC-MS non-target database (1/3)



Identification of components by 3 different parameters:

1. GC retention time
2. Mass spectrum (exact mass)
3. MS/MS fragment pattern



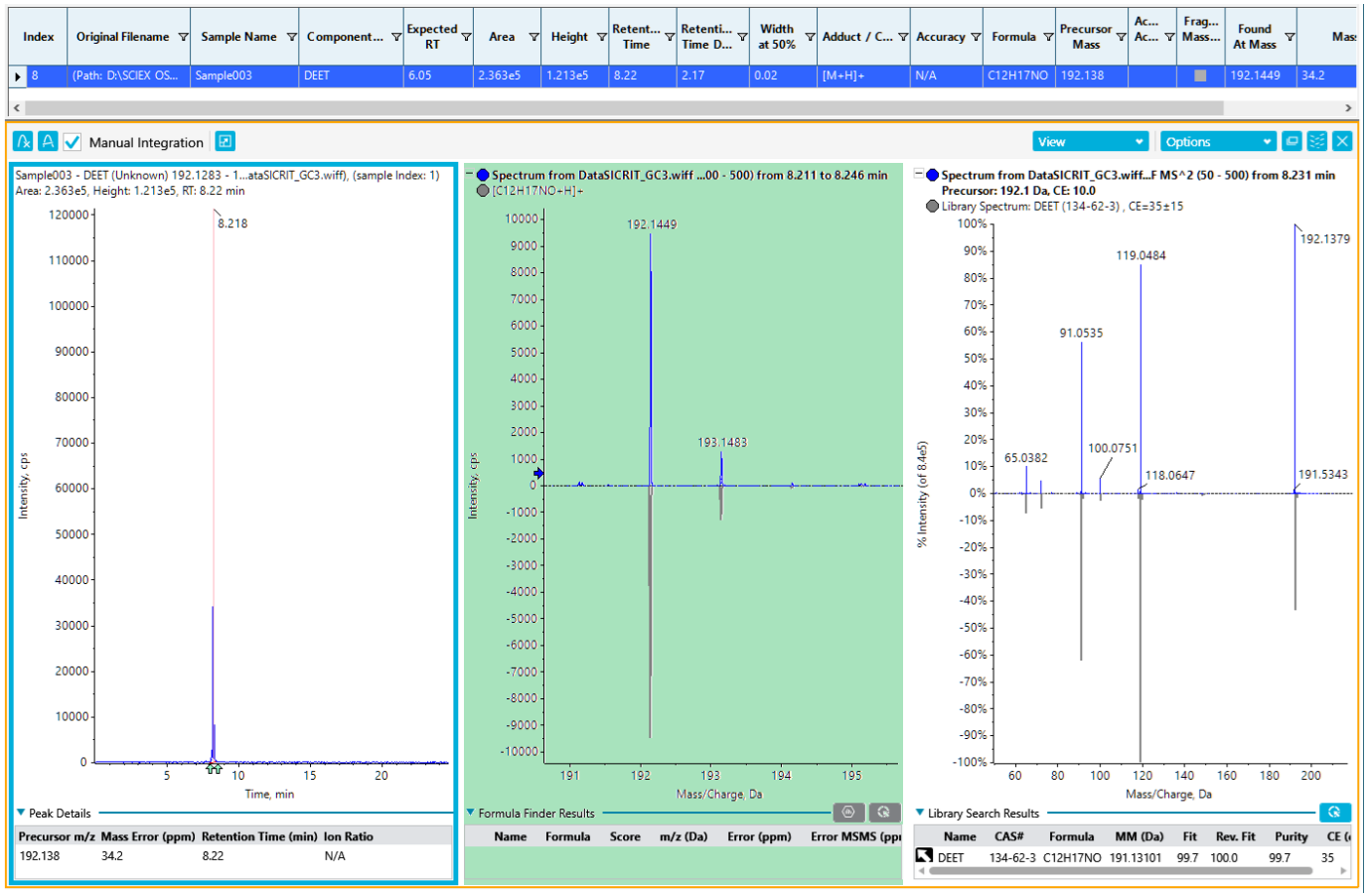
Diethyltoluamid

Exact mass: 191.1310

Detected as: $[MH]^+$

✓ Correctly identified

2 Automated identification after GC-SICRIT®-MS run due to LC-MS non-target database (2/3)



Identification of components by 3 different parameters:

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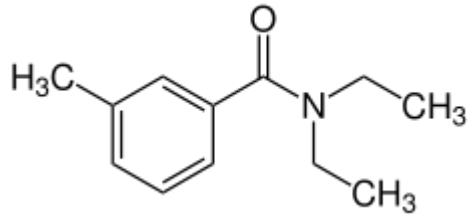
2. Mass spectrum (exact mass)
3. MS/MS fragment pattern



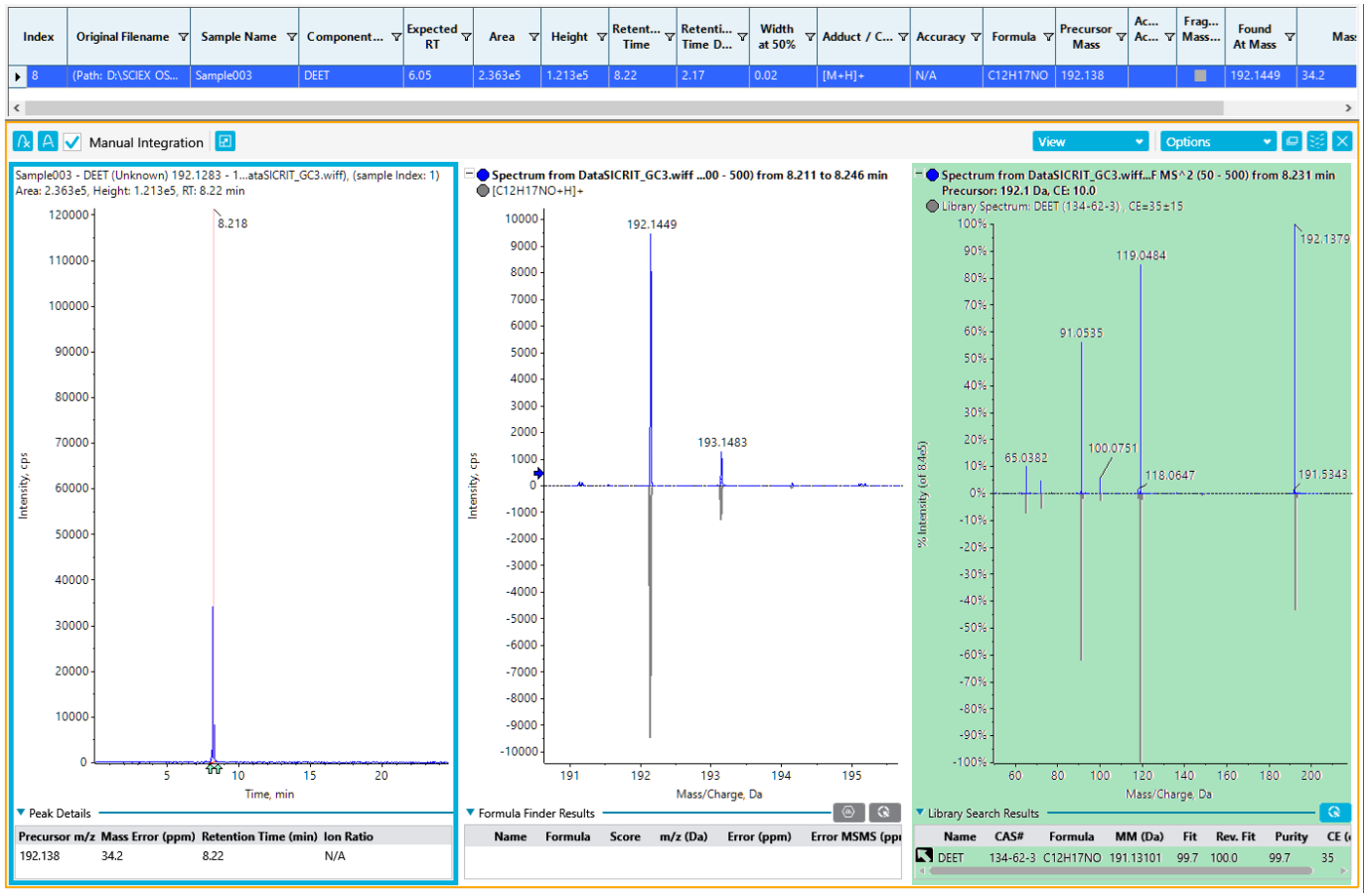
Diethyltoluamid

Exact mass: 191.1310

Detected as: $[MH]^+$

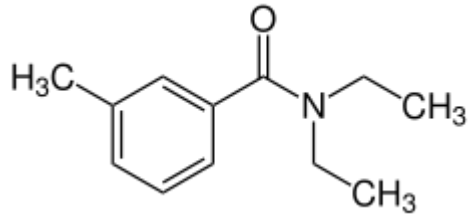
✓ Correctly identified

2 Automated identification after GC-SICRIT®-MS run due to LC-MS non-target database (3/3)



Identification of components by 3 different parameters:

1. GC retention time
2. Mass spectrum (exact mass)
3. MS/MS fragment pattern



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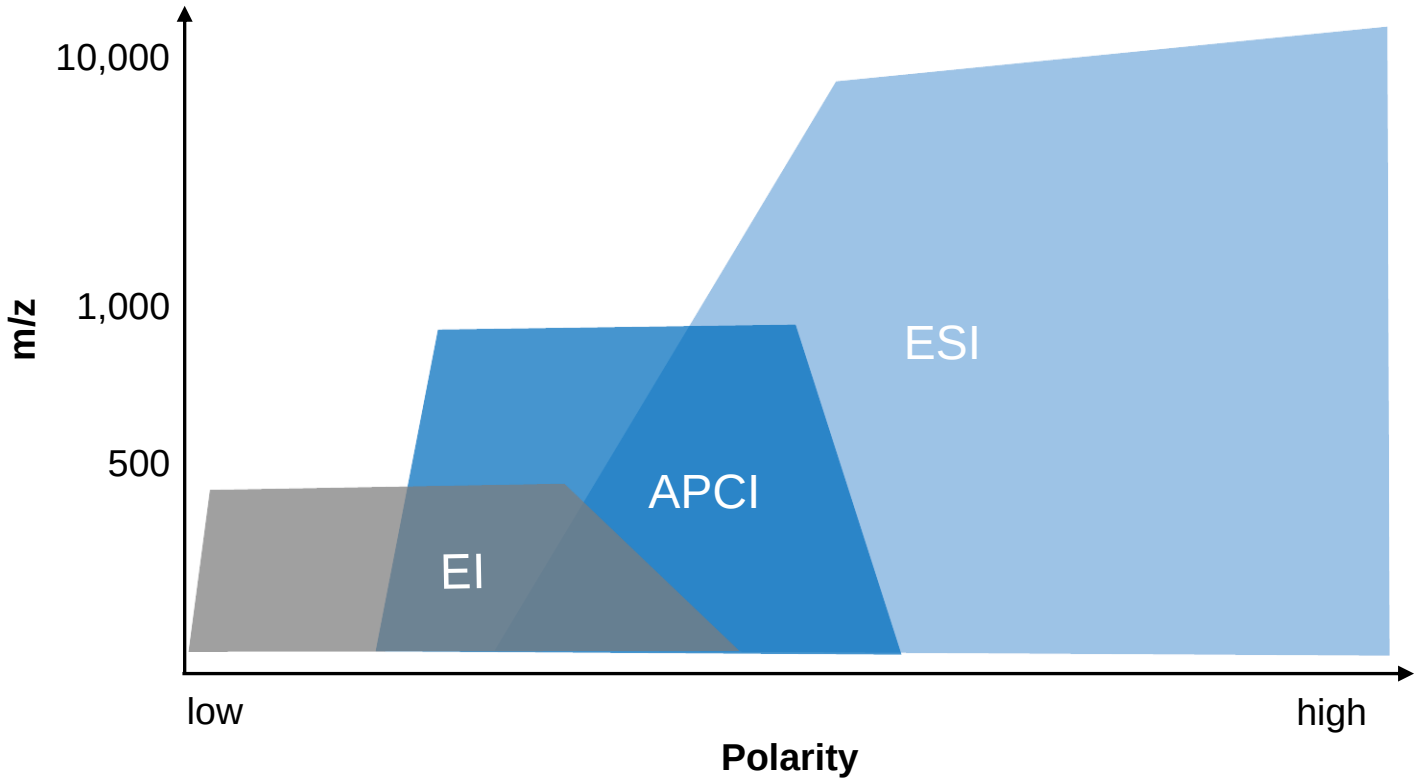
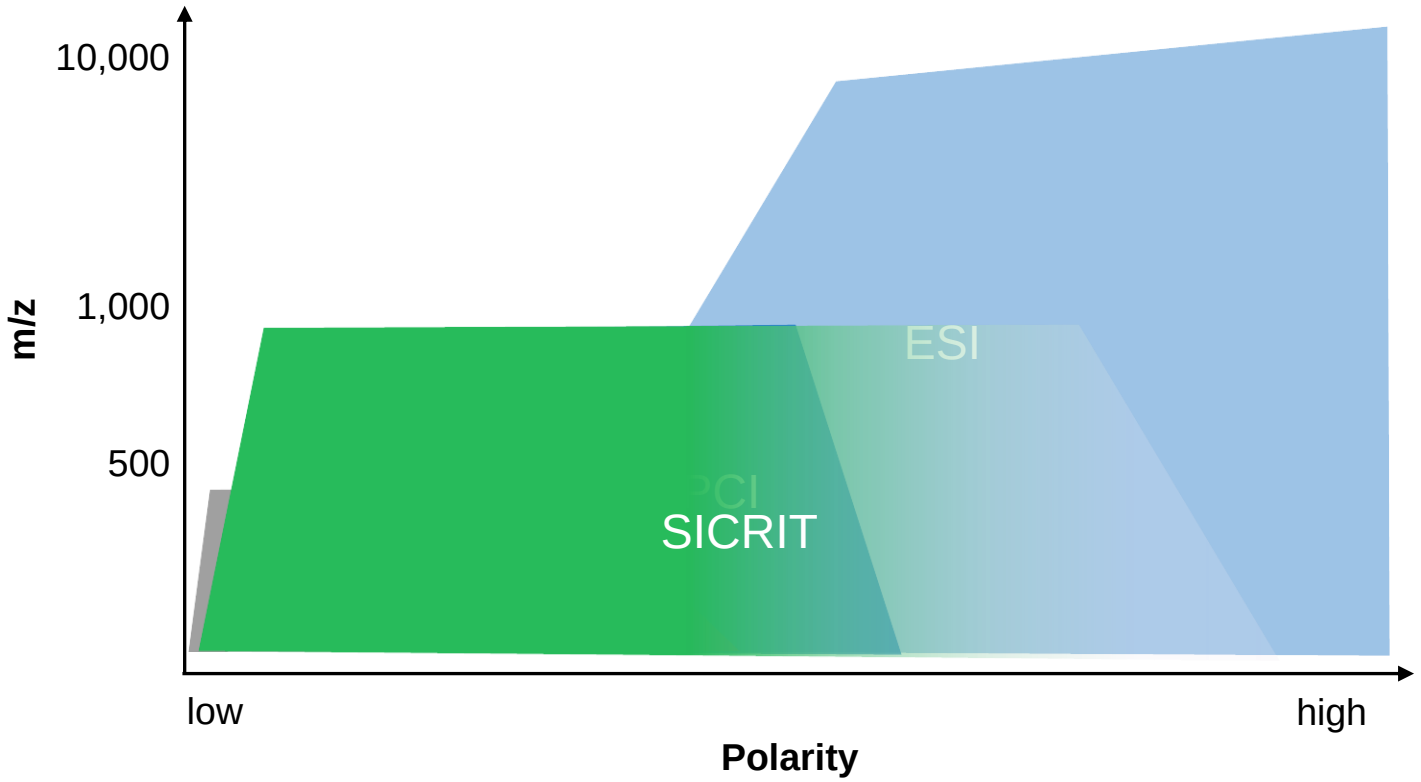
SICRIT® enables to cover a broad ionization range that previously required several separate systems

Schematic illustration of different ionization techniques



SICRIT® enables to cover a broad ionization range that previously required several separate systems

Schematic illustration of different ionization techniques



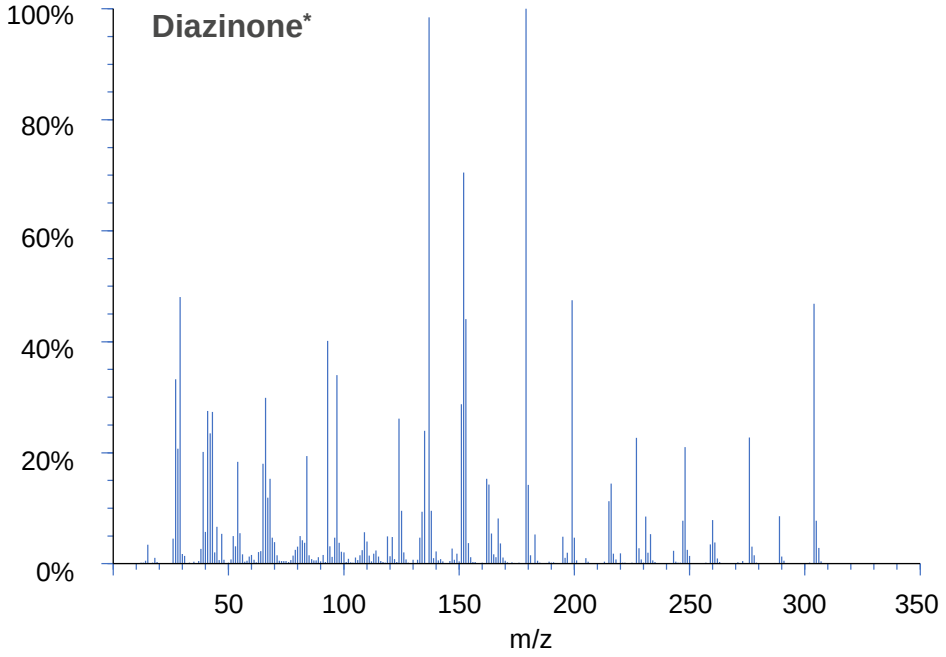
Indicative comparison

- **SICRIT®** is **capable to cover** the complete ionization range of **APCI** without having major drawbacks in terms of sensitivity
- **SICRIT®** is **capable to cover** almost the whole ionization range of **EI** without drawbacks in terms of sensitivity. The **exception** are **residual gases** like N_2, O_2, etc. that cannot be covered with the SICRIT® ionization mechanism
- Up to a m/z-ratio of 2000, **SICRIT®** is also **capable to cover** a **big chunk of** the ionization range that currently can only be covered by **ESI**. However, large biomolecules like proteins, etc. are still only detectable by **ESI**

The soft ionization mechanism of SICRIT® is a huge advantage in terms of identification

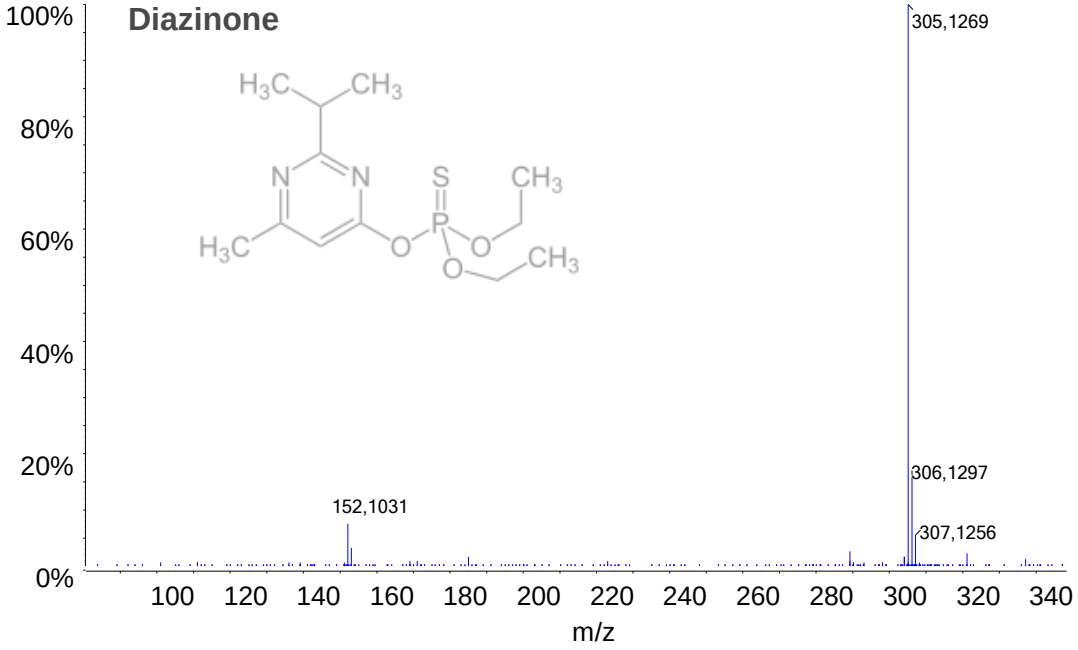
Fragmented Spectrum of Electron Impact Ionization

- **Molecular ion peak** in spectrum **almost not recognizable**
- Allocation of different fragments to enable **rigor conclusion** to original molecular ion peak is **challenging and time consuming**



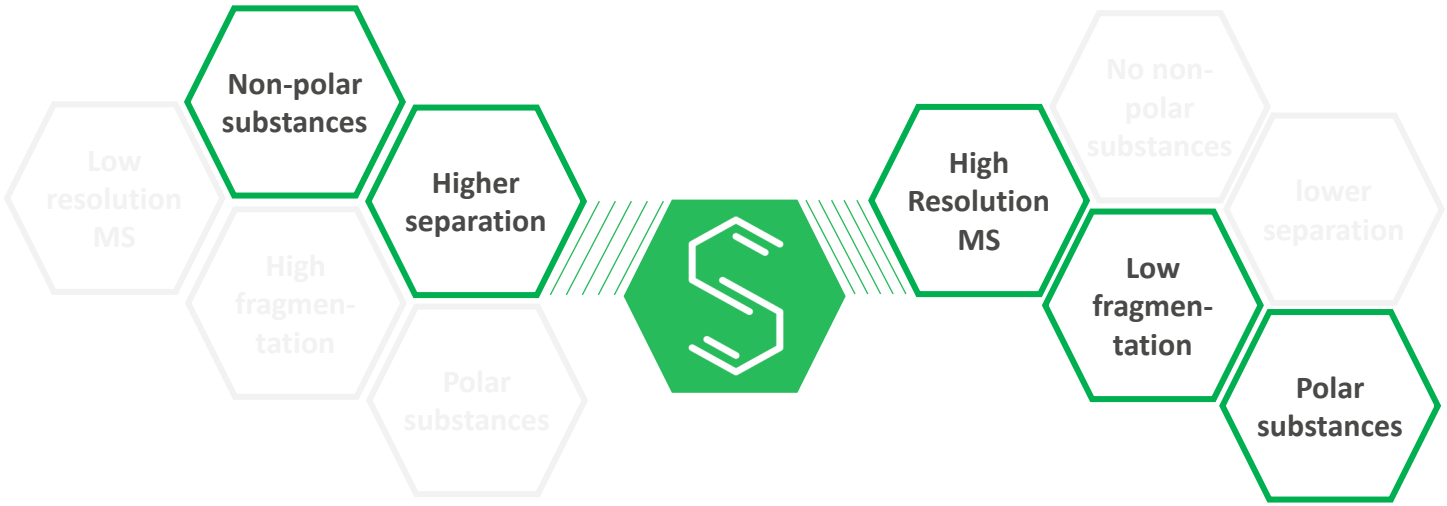
Spectrum of SICRIT® - Almost No Fragmentation

- Soft ionization mechanism of **SICRIT®** enables **immediate recognition of molecular ion peak** and delivers **rigor results more quickly** by avoiding complex allocation of different fragments



*NIST Chemistry Webbook: https/webbook.nist.gov/chemistry

SICRIT® is a unique bridge between the GC and the LC world and provides 5 major advantages



SICRIT® GC-Coupling Advantages

1. Combination of LC-MS detection and GC separation enables more **rigor and fast identification** of analytes
2. Ionization mechanism allows to cover a **broader range of analytes** – previously different systems required
3. Soft ionization delivers **molecular ion peaks** and **avoids** complex and challenging allocation due to **fragmentation**
4. Soft ionization allows to apply advanced detection models like **SWATH** or **Data Dependent Acquisition** (DDA)
5. Combination with HRMS enables addition **reliability** in terms of **substance identification**

Thanks for your attention!

Interested in more information?

Get in touch!

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