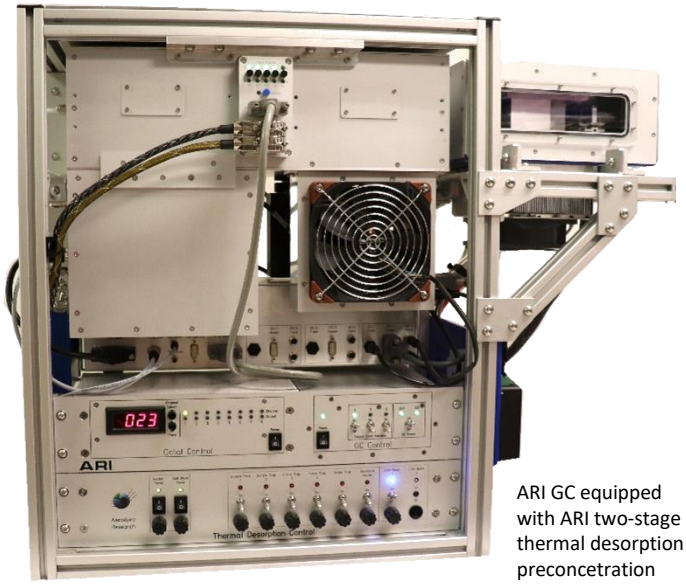
AERODYNE RESEARCH, Inc.

ARI Gas Chromatograph

A field-deployable modular GC for time-of-flight mass spectrometry (TOF-MS)



ARI GC equipped with ARI two-stage thermal desorption preconcetration system

Features:

Flexibility – up to three GC columns depending on application, pre-concentration methods (e.g. thermal desorption vs cryo-mechanical), detector type(s)

Field deployable – ruggedized GC with small, light-weight, footprint for automated operation

Detector compatibility – true plug-and-play operation with all ARI TOF-MS systems (hardware and software, including Tofwerk Acquility)

Dual detectors – designed to operate automatically with two detectors for a more complete data set

Turn-Key – ready-to-run on delivery due to pre-installed analytical column(s) with custom pre-loaded method(s)

Speed – flow path allows user to perform multiple GC operations at once; the benefit of this parallel operation is a faster GC cycle (10 – 30 min) without loss of performance

GC Technology

Aerodyne Research, Inc. (ARI) offers a modular gas chromatograph (GC) that combines recent innovations in fast GC separation with highly selective and sensitive detection in a field-deployable package for the measurement of VOCs and OVOCs.

Aerodyne works with our customers to provide a GC system with a ***custom separation method*** appropriate for their analytical needs. The instrument delivers with the required capillary column installed and analytical methods pre-loaded into the Windows-based control software, for a true ***turn-key*** operation.

Data Analysis Software

Wavemetrics Igor Pro analysis software (TERN) allows for retention time correction, automated baseline and peak fitting. TERN provides de-convoluted peak fitting for overlapping chromatographic peaks. Compatible for analysis of both high resolution (HR) and unit mass resolution (UMR) data.

Compatible Accessories

Sample Preconcentrators

ARI Thermal Desorption (TDPC)

ARI Cryomechanical (CMPC)

Other commercial preconcentration systems

Direct Injection Methods

Passivated sample loop (0.005 – 1 mL)

Split/Splitless Injection Port

Commercial autosamplers

Detectors

Vocus PTR-TOF-MS

EI-TOF-MS

CIMS-TOF-MS

Other commercial detectors (Q-MS, FID, ECD, etc.)

Performance Specifications:

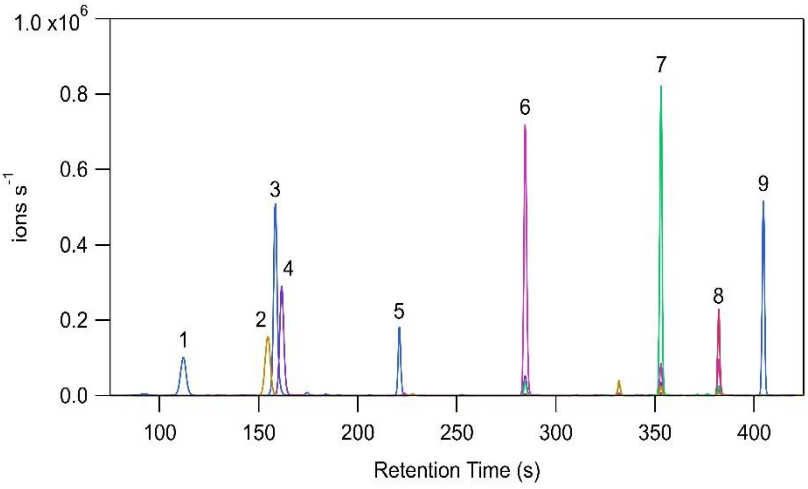


Figure 1. ARI GC equipped with ARI two-stage thermal desorption preconcetration system with EI-TOF detection (TD-GC-EI-TOF). Analysis of multi-component calibration mixture in nitrogen. 1000 mL sample of 0.75 ppb each (1) n-hexane, (2) carbon tetrachloride, (3) 2,2,4-trimethylpentane, (4) benzene, (5) n-octane, (6) ethyl benzene, (7) 1,3,5-trimethylbenzene, (8) limonene, (9) n-undecane.

Column Oven Specifications

Max heating rate: 120 °C/min
Max cooling rate: 250 °C/min
Max temperature: 260 °C
Temperature accuracy: ± 0.5 °C (ramped);
± 0.25 °C (isothermal)

Column compatibility: all fused silica and metal columns (60m @ ≤0.32mm ID, 30m @ ≥0.53mm ID)

Capillary columns are swappable without venting detector

Sampling / Reagent Gas Specifications

3-inlet system for analysis of sample (ambient), zero, and calibration gases

Sample gas: -40 to 50 °C; 0-90% RH; 50-125 kPa

Carrier gas compatibility: helium, nitrogen, hydrogen

Sample flow rate: up to 200 sccm, ± 1% accuracy

Carrier gas flow rate: up to 10 sccm

Complete inert/passivated sample flow path
(e.g. PFA, SilcoTek Siltek/Sulfinert passivated stainless steel)

Data Outputs

USB

Weight, Size, Power

Weight: 24 kg

Dimensions: 55 cm x 55 cm x 30 cm

Max power: 600 W, 120/240 V, 50/60 Hz (start-up)
300 W (typical operation)

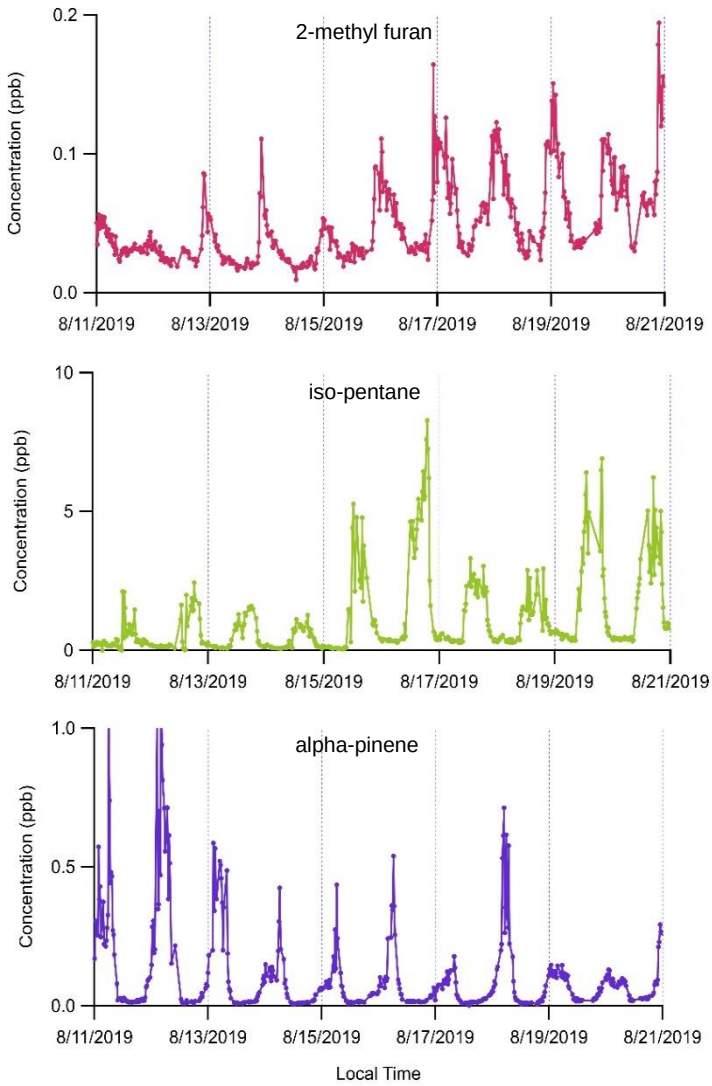


Figure 2. Ambient data acquired with ARI GC equipped with ARI two-stage thermal desorption preconcetration system with EI-TOF detection (TD-GC-EI-TOF)

Aerodyne specializes in collaboration and custom design. Please contact us if you would like to discuss additional measurement options and applications.

REFERENCES:

Claflin, M. S., et al. (2021) Atmos. Meas. Tech. 14: 133-152. doi: 10.5194/amt-14-133-2021
Lerner, B. M., et al. (2017) Atmos. Meas. Tech. 10(1): 291-313. doi: 10.5194/amt-10-291-2017
Isaacman-Van Wertz et al. (2017) J Chromatogr A; 1529:81-92. doi: 10.1016/j.chroma.2017.11.005

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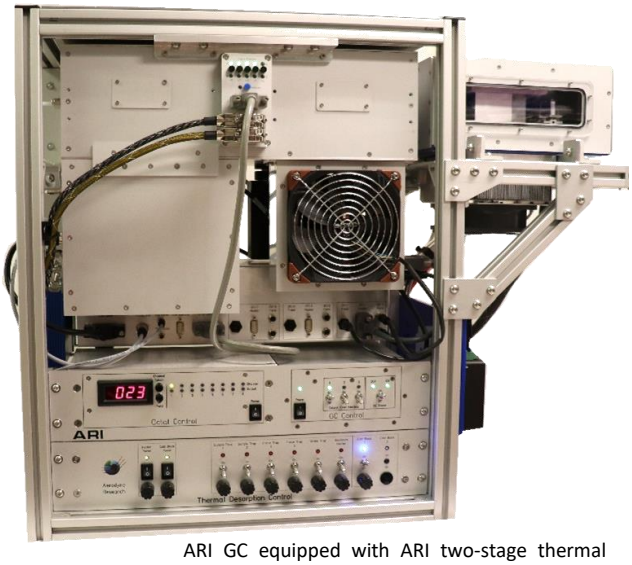
ARI TDPC-GC for TOF-MS

A field-deployable, in situ thermal desorption preconcentration (TDPC) system for the Aerodyne gas chromatograph (GC) with time-of-flight mass spectrometry (TOF-MS).

Mating the Aerodyne two-stage TDPC with the ARI GC expands the use of the GC system to a wide range of environmental applications. The system allows the user to automatically collect and analyze ambient air samples with sub-ppt sensitivity.

The first stage allows fast collection (maximum 150 sccm) of large samples (1 L of air, typical) with post-collection water purge of the sample in humid environments. The sample is then transferred to the second stage to focus the sample into a narrow injection onto the GC column.

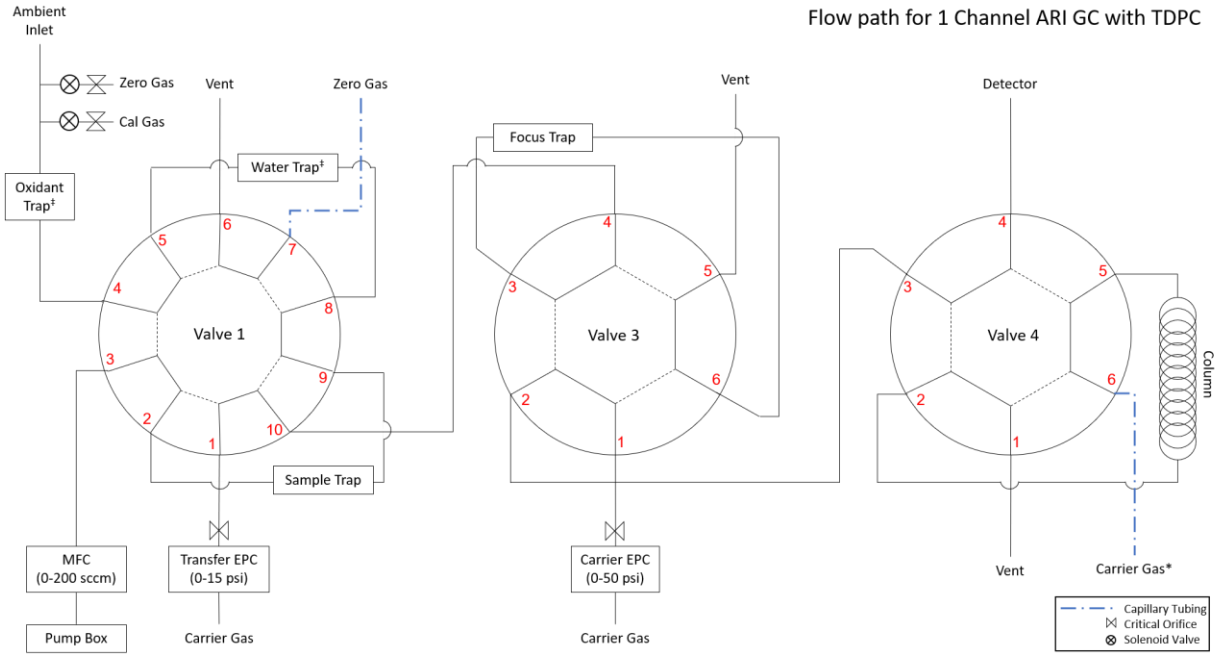
Using a three 2-port chromatography valve flow path gives the user 8-modes of operation. These 8 modes allow various functions of the GC to be conducted in parallel without interfering in the analysis. For example, the user is able to collect sample onto the first stage of the TDPC while simultaneously analyzing a chromatogram.



ARI GC equipped with ARI two-stage thermal desorption preconcentration system

The benefit of this parallel operation is a faster GC cycle, 15 – 30 minutes, without the loss of performance.

Flow path for 1 Channel ARI GC with TDPC



Sub parts-per-trillion sensitivity

The coupling of the TDPC for online sampling with the chromatographic separation of the ARI GC results in limits of detection < 1 ppt for a wide range of atmospherically relevant compounds (see Appendix I) with average R^2 of 0.996 (see Appendix II).

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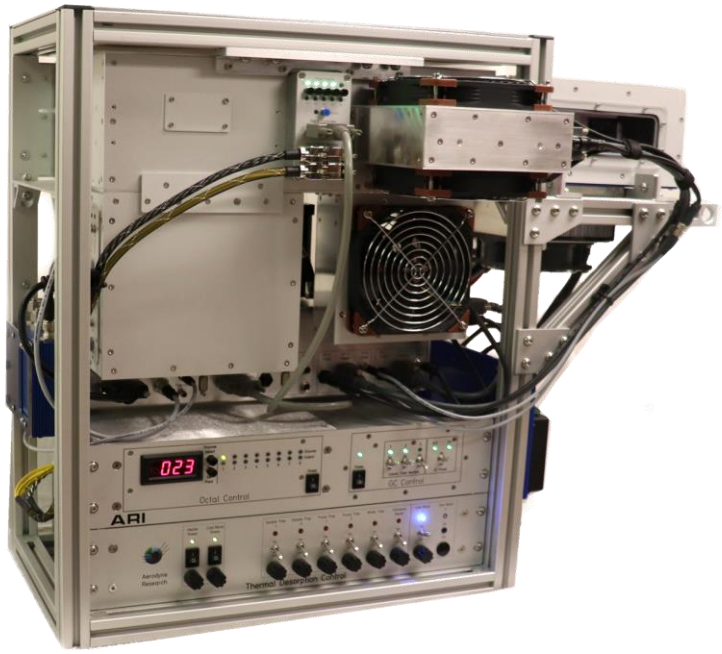
ARI TDPC-GC with 2 Column Separation



2-Channel ARI GC equipped with ARI two-stage thermal desorption preconcentration system

The ARI TDPC-GC for TOF-MS is available as a 2-channel system for the in situ analysis of VOCs and OVOCs.

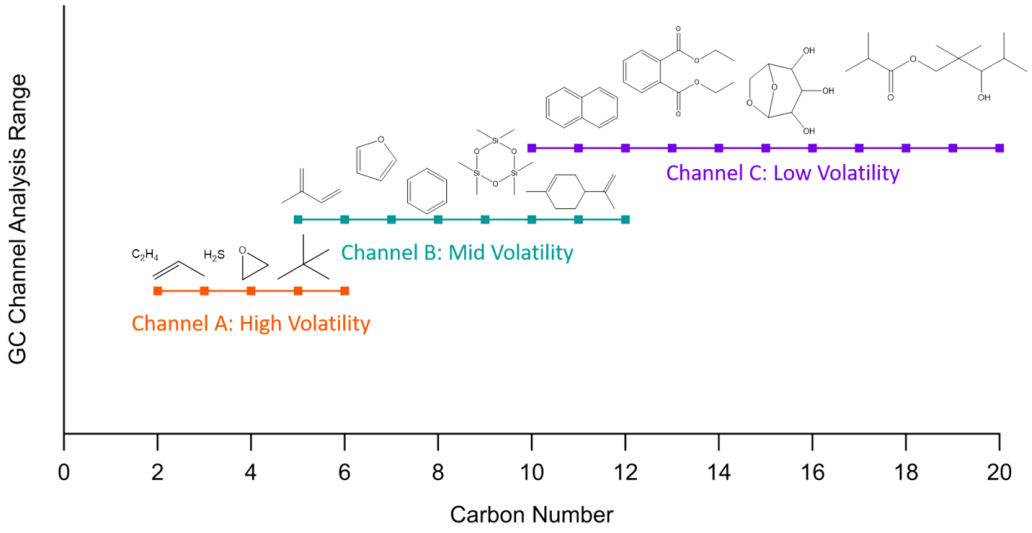
The 2-channel system operates with a 2 column separation for the analysis of a wider volatility range.

Each GC separation channel is optimized for a different volatility range to expand the types of compounds resolved by the GC, while maintaining a fast GC cycle.

The 2-Channel ARI TDPC-GC system operates on a 30 minute cycle (typical), which includes sample preconcentration, post collection water purge, and a 10 minute chromatogram from each separation channel.

The user can choose a combination of volatility ranges that fits their analysis needs. The combination of Channels A and B will resolve C_2 – C_{12} VOCs, while the combination of Channels B and C will resolve C_5 – C_{20} VOCs.

If the users analysis needs change, either separation channel is easily modified by swapping in a different column assembly. This switch takes less than 15 minutes, and is done without venting the detector.



Example volatility ranges offered with the ARI GC. The 1-Channel ARI GC system is able to resolve one of these separation ranges, while the 2-Channel system can resolve a combination of Channels A, B, or C for the analysis of a wider range of VOCs and OVOCs.

The molecular structures shown are examples of compounds in the analysis range of each GC channel, but compounds that can be resolved by each channel are not limited to those shown.

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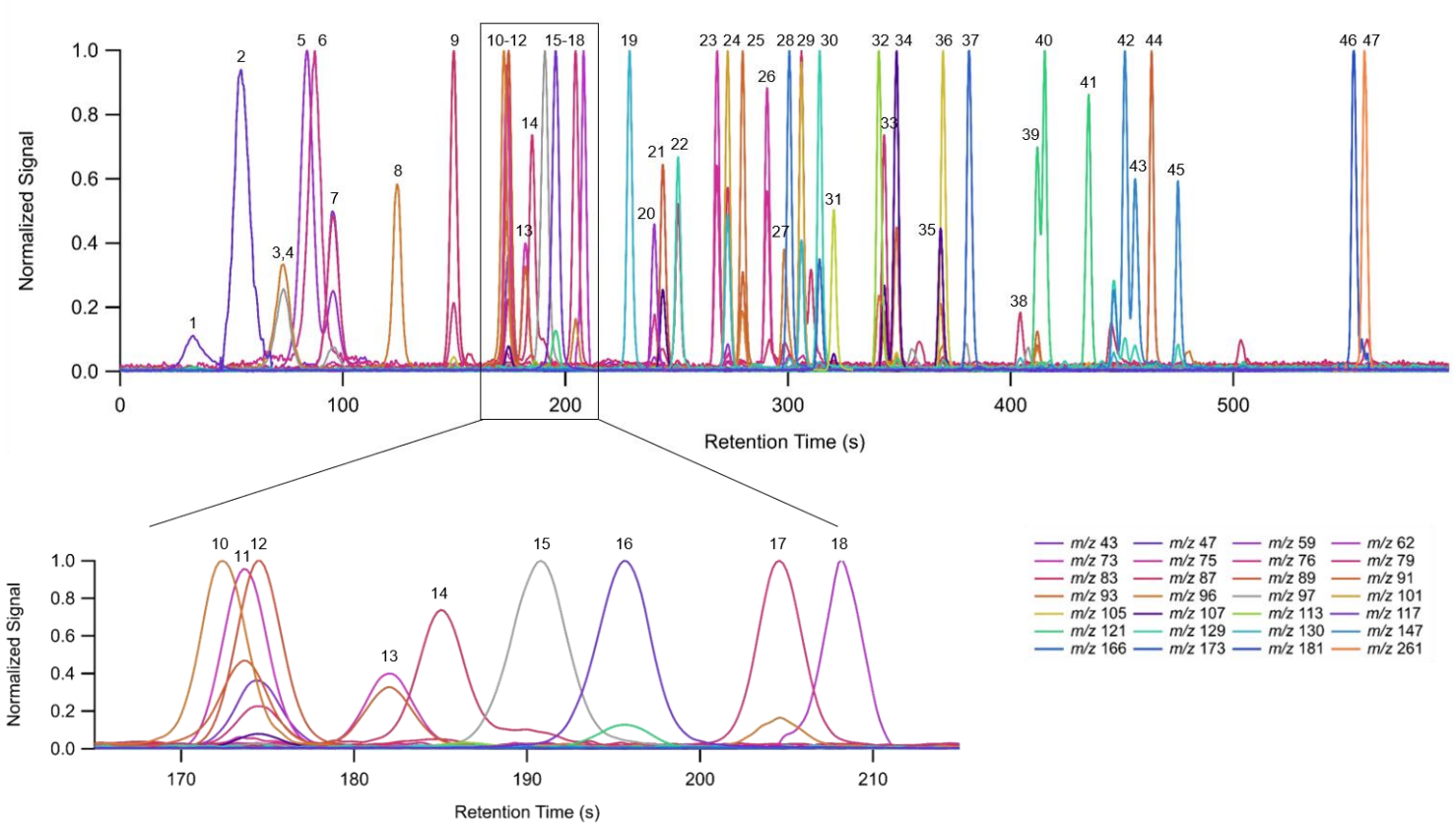
Exemplary ARI TDPC-GC-Vocus Chromatogram

Aerodyne TDPC-GC chromatographic separation of a selection of atmospherically relevant VOCs, detected with Vocus PTR-TOF-MS (proton transfer reaction time-of-flight mass spectrometry).

Figure shows a 10 minute chromatographic separation typically performed by the ARI GC system.



1	trichlorofluoromethane	13	tetrahydrofuran	25	toluene	37	bromoform
2	ethanol	14	chloroform	26	trans-1,3-dichloropropene	38	1,1,2,2-tetrachloroethane
3	1,1-dichloroethylene	15	1,1,1-trichloroethane	27	1,1,2-trichloroethane	39	4-ethyltoluene
4	1,1,2-trichloro-1,2,2-trifluoroethane	16	carbon tetrachloride	28	tetrachloroethylene	40	1,3,5-trimethylbenzene
5	acetone	17	benzene	29	2-hexanone	41	1,2,4-trimethylbenzene
6	carbon disulfide	18	1,2-dichloroethane	30	dibromochloromethane	42	1,3-dichlorobenzene
7	2-propanol	19	trichloroethylene	31	1,2-dibromoethane	43	1,4-dichlorobenzene
8	trans-1,2-dichloroethylene	20	1,2-dichloropropane	32	chlorobenzene	44	benzyl chloride
9	vinyl acetate	21	1,4-dioxane	33	ethylbenzene	45	1,2-dichlorobenzene
10	cis-1,2-dichloroethylene	22	bromodichloromethane	34	m&p-xylenes	46	1,2,4-trichlorobenzene
11	2-butanone	23	cis-1,3-dichloropropene	35	o-xylene	47	hexachloro-1,3-butadiene
12	ethyl acetate	24	4-methyl-2-pentanone	36	styrene		

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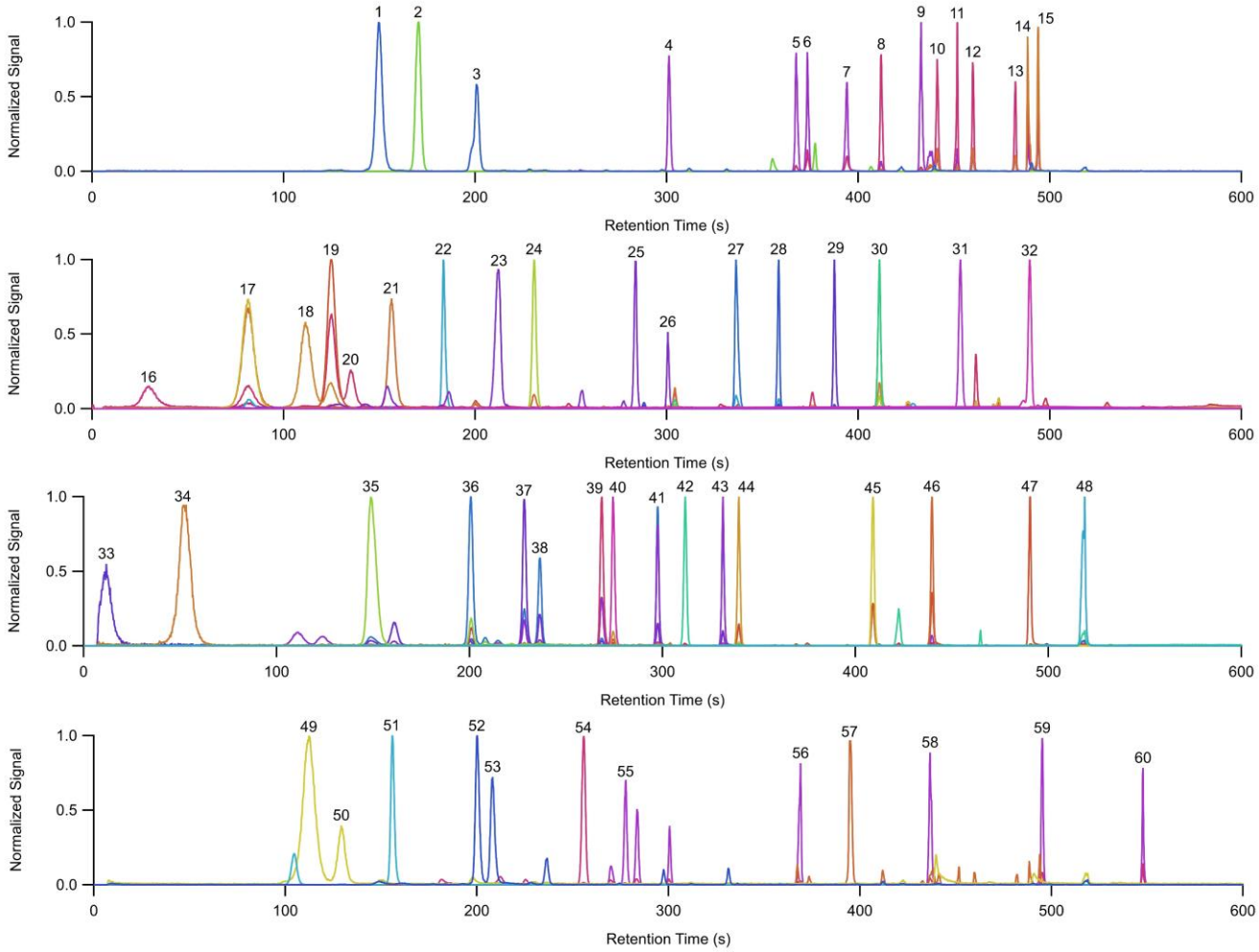
Exemplary ARI TDPC-GC-EI-TOF Chromatogram

Aerodyne TDPC-GC chromatographic separation of a selection of atmospherically relevant VOCs, detected with EI-TOF-MS

Figure shows 10 minute chromatographic separation of 60 atmospheric VOCs. Note that species are separated into 4 plots for clarity, but are resolved in a single 10 minute chromatogram.



1	trans-$C_2H_2Cl_2$	16	methanol	31	beta-pinene	46	4-ethyl toluene
2	CCl_4	17	isoprene	32	cymene	47	benzyl chloride
3	ethyl acetate	18	acetone	33	butadiene	48	D5-siloxane
4	toluene	19	isopropanol	34	vinyl bromide	49	carbon disulfide
5	ethyl benzene	20	acetonitrile	35	methyl tert-butyl ether	50	allyl chloride
6	m&p-xylenes	21	acrylonitrile	36	vinyl acetate	51	n-hexane
7	o-xylene	22	tert-amyl ethyl ether	37	2,2,4-trimethyl pentane	52	methyl ethyl ketone
8	i-propyl benzene	23	cyclohexane	38	n-heptane	53	tetrahydrofuran
9	n-propyl benzene	24	benzene	39	1,4-dioxane	54	methyl cyclohexane
10	3-ethyl benzene	25	3-methyl heptane	40	$CHCl_2Br$	55	2-methyl heptane
11	2-ethyl benzene	26	n-octane	41	4-methyl-2-pentanone	56	n-nonane
12	1,2,4-trimethyl benzene	27	D4-siloxane	42	D3-siloxane	57	styrene
13	1,3,5-trimethyl benzene	28	1,2,3-trimethyl benzene	43	2-hexanone	58	n-decane
14	m-diethyl benzene	29	limonene	44	$CHBr_2Cl$	59	n-undecane
15	p-diethyl benzene	30	alpha-pinene	45	$CHBr_3$	60	n-dodecane

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Linearities (R^2) and limits of detection (LOD) for a variety of atmospherically relevant compounds measured by Aerodyne TDPC-GC-Vocus PTR-TOF-MS

These R^2 and LOD values are measurements from 1 L pre-concentrated sample volumes collected at 100 sccm over analyte concentration ranges of 0.1 – 10 ppb.

Note that this table gives examples measured by the TDPC-GC-Vocus PTR-TOF-MS system, but compounds that can be resolved by the system ***are not limited to*** those specified on this list.

		R^2	LOD (ppt)[a,b]				R^2	LOD (ppt)[a,b]
	Aromatic Hydrocarbons					**Halocarbons**		
1	benzene	0.998	1.5		21	bromoform	0.997	1.3
2	toluene	0.989	0.8		22	carbon tetrachloride	0.999	0.4
3	styrene	0.990	0.7		23	chloroform	1.000	0.7
4	ethyl benzene	0.997	1.0		24	bromodichloro methane	0.999	0.8
5	m&p-xylenes	0.979	0.6		25	dibromochloro methane	0.996	0.9
6	o-xylene	0.977	1.5		26	trichlorofluoro methane	0.996	4.1
7	4-ethyl toluene	0.965	2.2		27	1,1-dichloro ethylene	0.998	2.8
8	1,2,4-trimethyl benzene	0.997	1.3		28	cis-1,2-dichloro ethylene	1.000	2.5
9	1,3,5-trimethyl benzene	0.994	1.1		29	trans-1,2-dichloro ethylene	1.000	2.7
					30	tetrachloro ethylene	0.996	1.8
	Misc. Oxygenates				31	trichloro ethylene	0.999	1.2
10	acetone	0.999	3.1		32	1,1,1-trichloro ethane	0.998	0.9
11	methyl ethyl ketone	0.993	1.4		33	1,1,2,2-tetrachloro ethane	0.997	2.2
12	2-hexanone	0.998	0.4		34	1,1,2-trichloro ethane	0.997	4.7
13	4-methyl-2-pentanone	0.997	0.3		35	1,2-dibromo ethane	0.998	0.8
14	ethanol	0.995	30		36	1,2-dichloro ethane	1.000	1.7
15	2-propanol	0.981	40		37	cis-1,3-dichloro propene	0.998	0.4
16	ethyl acetate	1.000	0.7		38	trans-1,3-dichloro propene	0.997	0.4
17	vinyl acetate	0.998	4.0		39	chloro benzene	0.997	0.8
18	1,4-dioxane	0.993	1.8		40	benzyl chloride	0.996	3.1
19	tetrahydro furan	0.998	2.5		41	1,2-dichloro benzene	0.996	7.2
20	carbon disulfide	0.999	1.6		42	1,3-dichloro benzene	0.992	1.6
					43	1,4-dichloro benzene	0.996	2.6

[a] Limit of detection reported in units of parts-per-trillion (ppt)
[b] Limit of detection calculated as 3σ of the baseline, measured at 3x FWHM before and after elution time.

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Linearities (R^2) and limits of detection (LOD) for a variety of atmospherically relevant compounds measured by Aerodyne TDPC-GC-EI-TOF

These R^2 and LOD values are measurements from 1 L pre-concentrated sample volumes collected at 100 sccm over analyte concentration ranges of 0.1 – 10 ppb.

Note that this table gives examples measured by the TDPC-GC-EI-TOF system, but compounds that can be resolved by the system ***are not limited to*** those specified on this list.

		R^2	LOD (ppt)[a,b]				R^2	LOD (ppt)[a,b]
	Hydrocarbons					**Halocarbons**		
1	isoprene	0.996	0.8		41	bromoform	0.996	0.1
2	cis-2-pentene	0.933	6.2		42	carbon tetrachloride	0.998	0.1
3	trans-2-pentene	0.957	6.0		43	chloroform	0.999	0.3
4	n-pentane	0.996	3.0		44	bromodichloro methane	0.999	0.2
5	i-pentane	0.980	5.0		45	dibromochloro methane	0.996	0.2
6	methyl cyclopentane	0.999	0.7		46	dichloro methane	1.000	0.9
7	1-hexene	1.000	6.6		47	trichlorofluoro methane	0.990	0.7
8	n-hexane	0.998	3.0		48	1,1-dichloro ethylene	1.000	0.3
9	cyclohexane	1.000	0.6		49	cis-1,2-dichloro ethylene	0.999	0.1
10	methyl cyclohexane	0.997	0.2		50	trans-1,2-dichloro ethylene	0.998	0.8
11	3-methyl pentane	0.998	2.4		51	tetrachloro ethylene	0.995	0.1
12	2-methyl hexane	0.993	0.3		52	trichloro ethylene	0.999	0.5
13	3-methyl hexane	0.979	0.7		53	1,1,1-trichloro ethane	0.998	0.2
14	n-heptane	0.998	0.8		54	1,1,2,2-tetrachloro ethane	0.997	0.6
15	2,3-dimethyl pentane	0.999	0.4		55	1,1,2-trichloro ethane	0.996	0.3
16	2,4-dimethyl pentane	0.999	2.1		56	1,1-dichloro ethane	1.000	0.3
17	2-methyl heptane	0.998	1.1		57	1,2-dibromo ethane	0.998	0.2
18	3-methyl heptane	0.999	1.0		58	1,2-dichloro ethane	1.000	0.5
19	n-octane	0.999	0.4		59	cis-1,3-dichloro propene	0.995	0.1
20	2,2,4-trimethyl pentane	0.999	0.1		60	trans-1,3-dichloro propene	0.995	0.3
21	2,3,4-trimethyl pentane	0.997	0.4		61	1,2-dichloro propane	0.999	0.3
22	alpha-pinene	0.991	0.2		62	chloro benzene	0.992	0.2
23	limonene	0.998	0.6		63	benzyl chloride	0.994	0.8
24	n-nonane	0.999	0.1		64	1,2-dichloro benzene	0.996	0.5
25	n-decane	1.000	0.2		65	1,3-dichloro benzene	0.998	0.2
26	n-undecane	1.000	0.5		66	1,4-dichloro benzene	0.995	0.4
27	n-dodecane	0.994	0.5					
						Aromatic Hydrocarbons		
					67	benzene	1.000	0.3
					68	toluene	0.996	0.2
	Misc. Oxygenates				69	styrene	0.999	0.2
28	acetone	1.000	1.0		70	ethyl benzene	0.998	0.2
29	methyl ethyl ketone	0.999	0.9		71	m&p-xylenes	0.999	0.3
30	2-hexanone	1.000	0.5		72	o-xylene	0.997	0.5
31	4-methyl-2-pentanone	1.000	0.6		73	i-propyl benzene	0.997	0.3
32	ethanol	1.000	1.2		74	n-propyl benzene	0.997	0.3
33	2-propanol	1.000	0.2		75	2-ethyl toluene	0.997	1.3
34	ethyl acetate	0.996	0.8		76	3-ethyl toluene	0.996	0.6
35	vinyl acetate	0.999	0.5		77	4-ethyl toluene	0.996	0.6
36	1,4-dioxane	0.999	0.3		78	1,2,3-trimethyl benzene	0.996	0.2
37	methyl tert-butyl ether	1.000	0.8		79	1,2,4-trimethyl benzene	0.997	0.6
38	amyl ethyl ether	0.999	0.2		80	1,3,5-trimethyl benzene	0.999	0.5
39	tetrahydro furan	0.999	0.9		81	1,3-diethyl benzene	0.997	0.3
40	carbon disulfide	1.000	0.7		82	1,4-diethyl benzene	0.998	0.3

[a] Limit of detection reported in units of parts-per-trillion (ppt)

[b] Limit of detection calculated as 3σ of the baseline, measured at 3x FWHM before and after elution time.