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Ion Mobility Spectrometry (IMS)

A useful Method for Detection and Determination of Narcotics, Abused Drugs and other Harmful Substances

Detection and identification and also monitoring of harmful substances, such as narcotics and abused drugs, chemical warfare agents (CWA), explosives, industrial and environmental poisons, play an important role in law enforcement, e.g. in the field of terrorism countermeasures as well as in public and private security also. This highly sophisticated equipment for law enforcement and other security staff is portable and working autonomously based on **IMS**. Due to its high sensitivity and working as an analytical „artificial noses“ experts often refer to it as true „sniffing dogs“.

There are only a few manufacturers of this type of high-tech and complex equipment world-wide. In Germany, the "Institute of Environmental Technologies Ltd." (**I.U.T.**), located in Berlin, has developed a special portable analytical system in modular construction for the above listed substance groups and purposes as demonstrated below:

High sensitivity for the different kind of harmful substances is reached by special alterations of the drift cell and ionisation system with the device being produced in the **types** as

- IMS-GSM Gas Trace Monitor
- IMS-CWM Chemical Warfare Agents (CWA) Monitor
- IMS-NARC Narcotic Agents Monitor
- GC-IMS Model GSM, additionally fitted a with multicapillary column.

Options:

- *Standard model* with drift cell (for gaseous samples only)
- *Model with heated sampling device for drying and desorption (*preparation of liquid, wet or solid samples with matrix)

TECHNICAL DATA

Ionisation source	Tritium (Beta-emitter), Activity up to 4,4 GBq depending on desired accuracy and customers demand.
Power consumption:	Up to 20 W (non heated cell, depending on the type), 4 - 6 hours autonomy with battery. Up to 48 W with heated cell and desorption chamber.
Display:	Alphanumerically, 4 x 40 signs.
Communication:	Serial port RS 232.

Operation temperature:	-10 up to +80°C (depending on the type).
Column temperature:	35, 60 and 80°C (Model GC-IMS only).
Measurements:	10“ or 19“ standard or according to users demand.
Weight:	6 - 8 kg (depending on the type).

General Aspects

IMS is a method to detect gas traces in the air and generally used to detect harmful substances in very small concentrations, for instance at workplace and environmental protection.
The I.U.T.- IMS described above is built of a highly durable construction and may be used in the field, e.g. by police and customs agencies, can be mounted in cars and construction site vehicles. It is easy to use with no particular training and requires only very little maintenance, if any.
The method resembles somewhat that used in mass spectrometry, but IMS works without vacuum under normal pressure. Experts refer to this analytical technology as "APCI = Atmospheric Pressure Chemical Ionisation".

TECHNICAL PRINCIPLE

A small sample of air containing the suspected substance, e.g. narcotics, is periodically taken into the IMS system where a radioactive source ionises the molecules in the sample. As a result of the charge, they drift into an electric field inside the so called „drift cell“.

When the ions reached the end of the drift cell, their charge induces an electric impulse at the counter electrode which is than amplified and measured. Each type of molecule has a typical drift velocity in the air and may therefore be identified.
This in such way recorded spectrum is further processed by a built-in computer with a 32-bit processor. Communication with an external computer (e.g. data exchange, recording spectra) can be accomplished by a serial port (RS 232).

Then the type of substance and its concentration is reflected on the display. By option the processor can switch on an alarm signal (optic, acoustic, other) reaching a threshold value or a cut-off level. The technical and constructing principles with main modules are shown in figures (2) and (3) below.

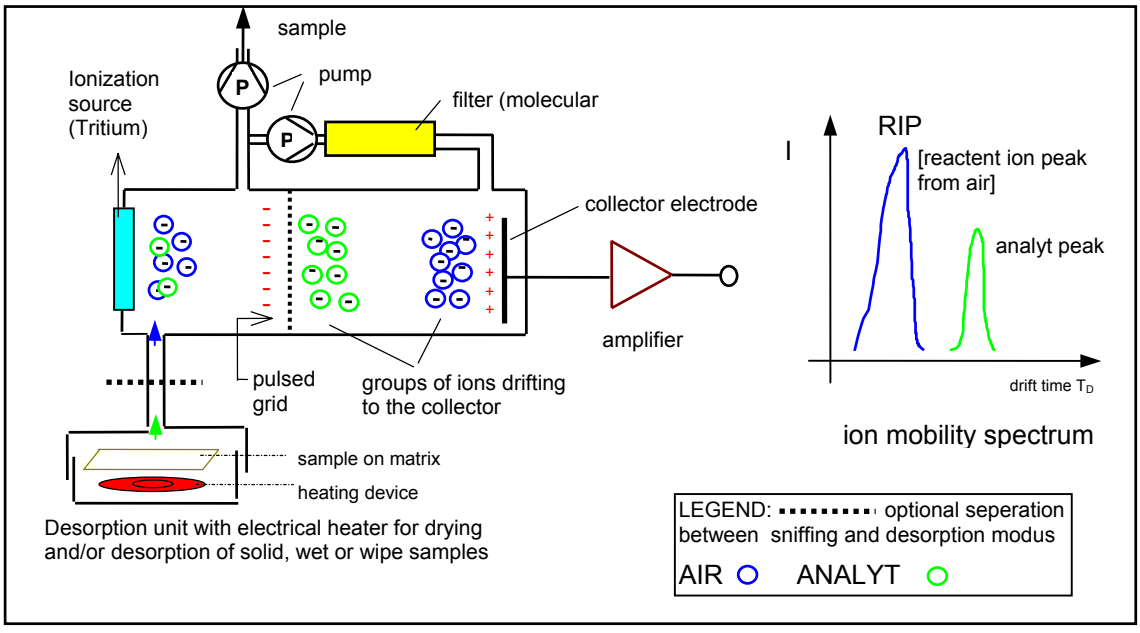

Fig.2: Technical principle of the used IMS.

The analytical system of the IMS is subject to strong defined requirements such as

- detection limit in the range smaller as 20 nanogram,
- elimination of accidental and intended disturbances and minimisation of cross-reactions,
- fast measuring regimes with screening rates in seconds, reading average values at 1-2 minutes and a deadtime of 2 minutes maximum,
- autonomy work and easy handling including self-test and teach-in process.

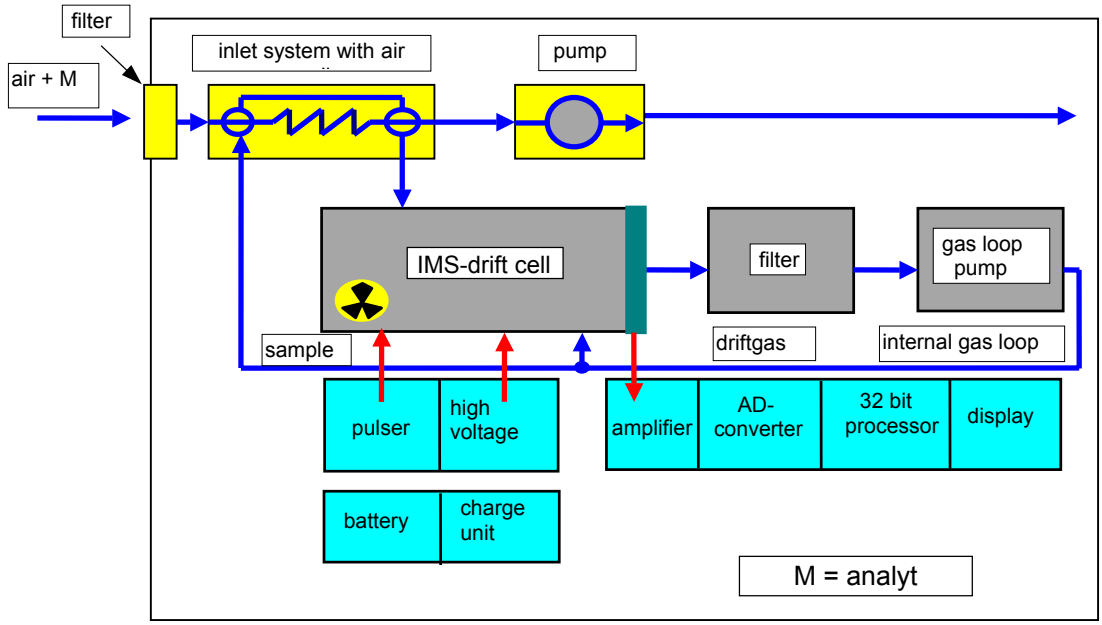

Fig.3: I.U.T. IMS, standard model GSM, constructing principle and main modules

The multicapillary column of the I.U.T. IMS technology

The I.U.T. IMS can optionally be fitted with an integrated multicapillary GC-column. This specially GC-column is driven with the internally produced purified air and thus does not require external resources such as helium or other GC-drift gases. This patented technology produces a three dimensional spectrum which allows identification of substances with more precision than a regular IMS (see fig. 5). By use of such column, the IMS is only exposed to one single substance at time. **Therefore, the cross sensitivity is reduced significantly**.

Applications (Selection)

- Detection of narcotics, drugs and other controlled substances (e.g. for use by police, customs, and forensic and emergency medicine);
- Detection of high toxic and dangerous substances, such as CWA and explosives (e.g. for use by military, police, other special forces);

- Monitoring and anti-terror security systems in important and/or air conditioned buildings (e.g. at the governmental German building "Reichstag" at Berlin);
- Environmental protection, especially emission control and monitoring;
- Air control for working place safety.

- Process and production control (e.g. doping gases in chip production);
- Detection and/or differentiation of highly aromatic substances/brands (e.g. coffee, tea, alcoholic and non-alcoholic beverages).

DETECTION and IDENTIFICATION

Detection and identification will generally be done by characteristic peaks and the relative drift time (simplified: the quotient of substance drift time and drift time of reaction peak). These values are obtained from the recorded spectrum of the single substances respectively their destruction products and/or peaks for some molecules with the same chemical structure. Latter is an important aid in recognising unknown substances by group-identification. While detection limits (MDC = Minimum Detectable Concentration) are in the range of ppb to ppt, IMS will detect normal nanogram and partly picogram amounts of suspected substances. Meanwhile, IMS is capable of identifying and listing more than 250 substances; identification of special substances are available on demand. An example for narcotics is shown in figure 4 while figure 5 shows an example for detection of CWA, three-dimensionally recorded with the GC-IMS. A selection of some other harmful substances detected by the **I.U.T. - IMS** is listed in table 2.

Detecting narcotics and abused drugs

In recent past, the use of narcotics and the number of users have alarmingly increased. Not only the common illegal substances like opiates, cannabis and cocaine, but also a great number of synthetic drugs such as amphetamines and other so called "Designer Drugs", especially Ecstasy (XTC, "Love Pills"), phencyclidines (PCP, "Angels Dust"), fentanyles ("Synthetic Heroin", e.g. "China White") indeed a very dangerous development which demands an equivalent answer:
Modern analytical devices for fast detection and identification of suspected substances for use by police, customs and, last but not least, forensic and emergency medicine.

The IMS-NARC is such a special developed device based on the regular **I.U.T.-IMS** (see above). It is portable and of light weight, can detect all suspected substances depending on their vapour pressure and identify most of the common narcotics, their additives and/or diluents and drugs of abuse

- in the **"sniffing modus"** without sample and laboratory processing only by measuring of the substance vapours in the ambient air;

- in the **"desorption modus"** for solid samples technology (e.g. pills, powdered and herbal drugs, sweat from skin surface, saliva, nasal secret, wipe samples from different surfaces such as clothing, documents, technical products et al.) without sufficient vapour pressure and wet/liquid samples by employment of a built-in sample processing technology.

As described above, detection and identification will be done by characteristic peaks for single substances respectively their destruction products and/or peaks for some molecules with same chemically structure, i.e. new or unknown narcotics and abused

drugs, for instance phenethylamines (e.g. ephedrine, amphetamine and precursors). Fig. 4 below show an example for usually amphetamine and ring-substituted derivatives, the Ecstasy drugs MDE, MDMA and MBDB.

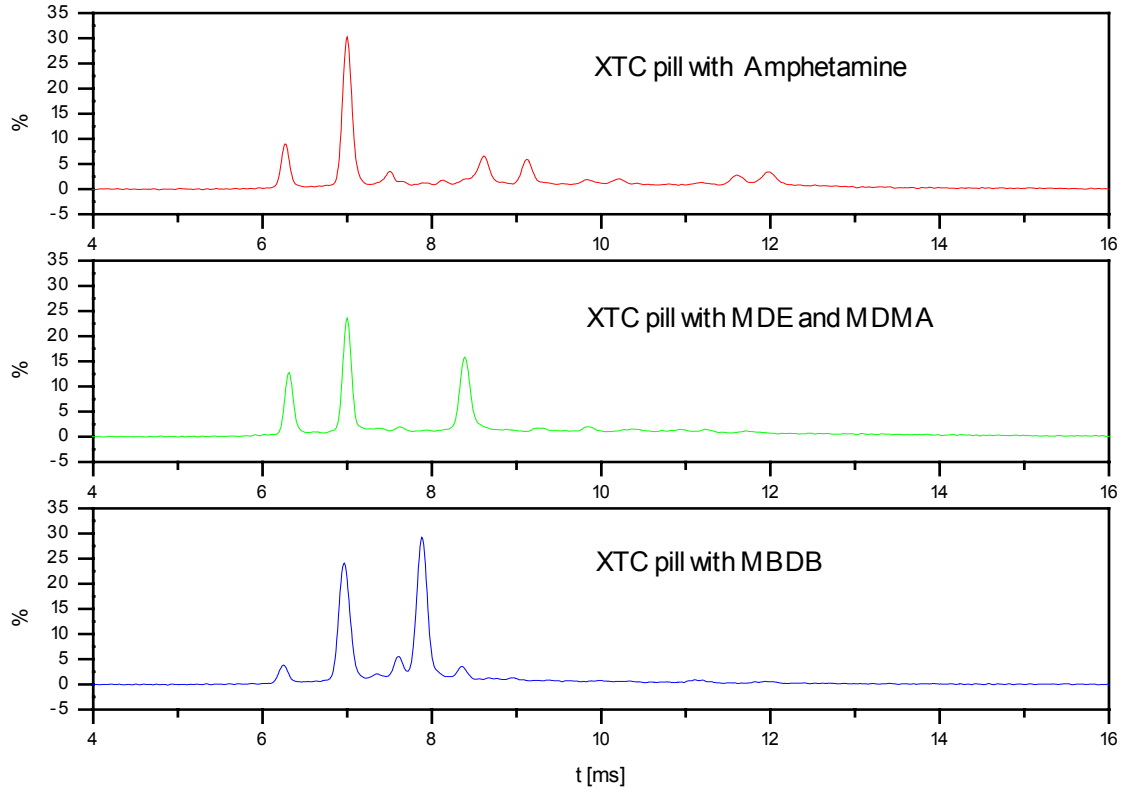

Fig. 4: IMS-spectra of street drug pills containing several amphetamines

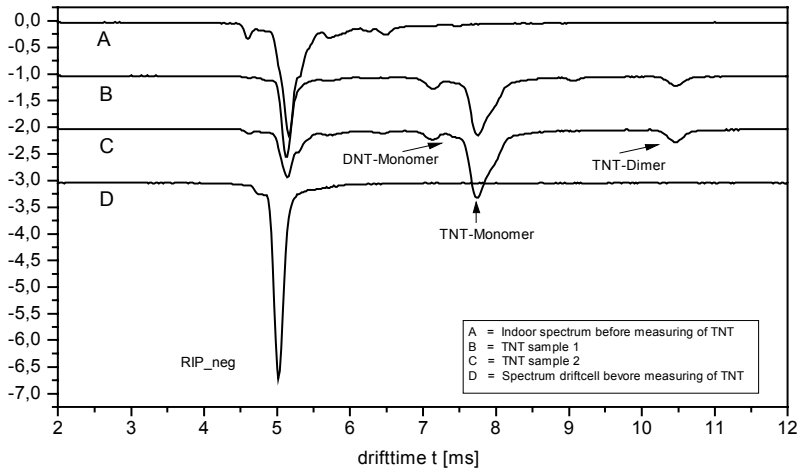

Fig. 5: IMS-spectra of the explosive TNT, technical grade;
[Y-axis: relative intensity]

Detection of Chemical Warfare Agents (CWA)

The below listed values are measured with IMS-CWM by NATO qualified independent TNO institute, Rijswijk, Netherlands, with exception of * marked values, measured by I.U.T. Ltd..

Nerve agents		Blister agents		Choking agents	
Agent VX	0,4	S-Mustard (agent HD)	2,1	Phosgene (agent CG)	50,0*
Soman (agent GD)	4,2	N-Mustard (agent HN)	19,0	Prussic acid (agent AC)	50,0*
Sarin (agent GB)	0,7	Lewisite (agent L)	15,0		
Tabun (agent GA)	0,4				

Table 1: Detection limits (µg/m3) of some important CWA

The picture below shows a three-dimensional ion mobility spectrum recorded from an IMS fitted with a multicapillary GC-column with the retention time as 3rd dimension.

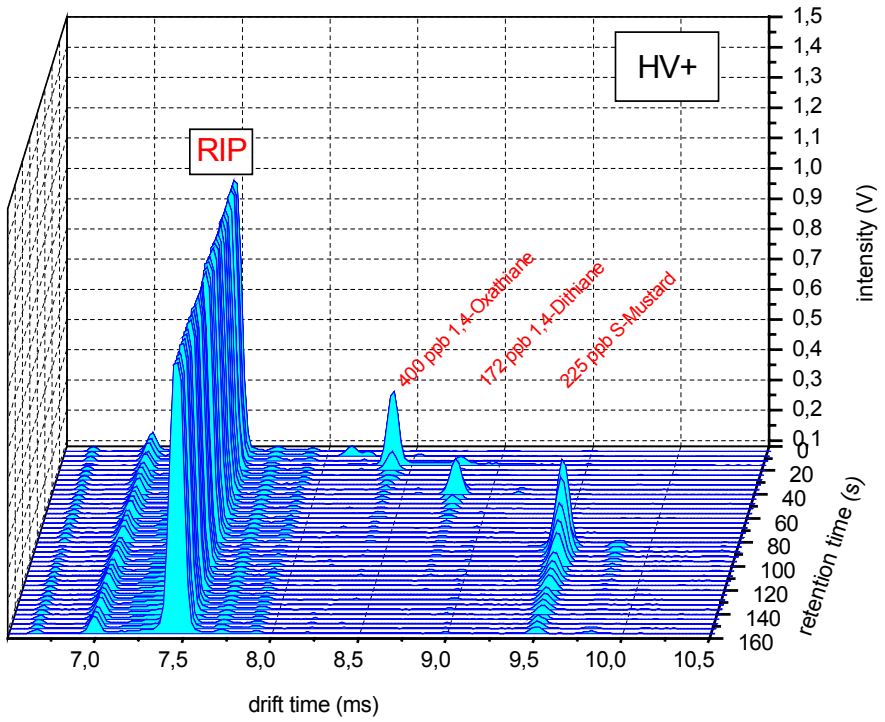

Fig. 6: Example for detecting CWA with GC-MS
[S-Mustard and two of its main destruction products]

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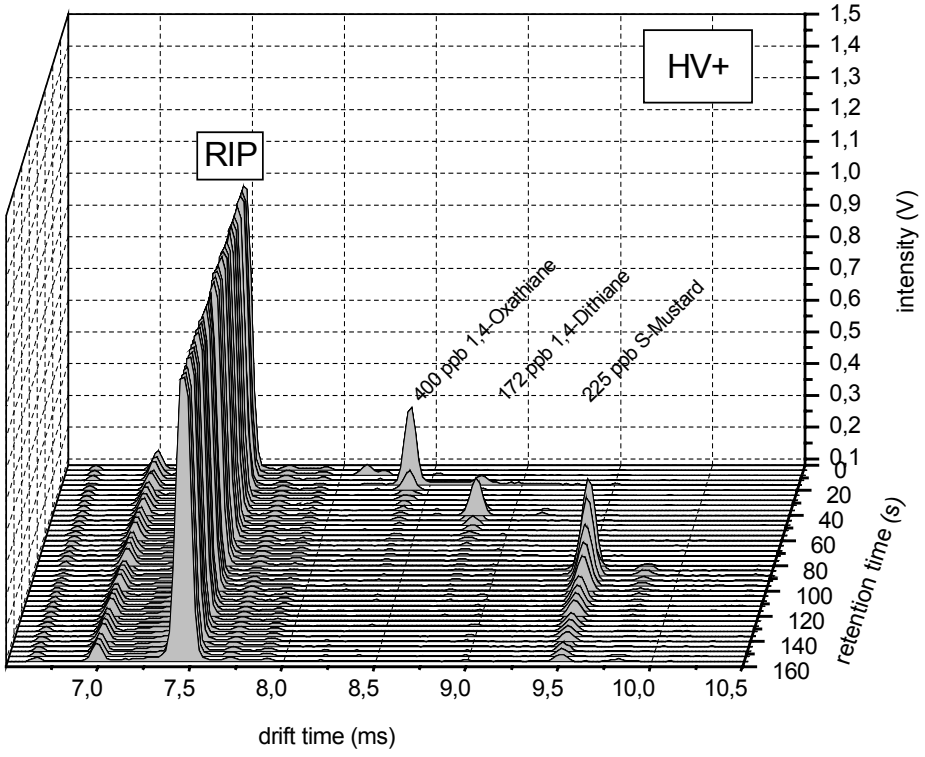

Fig. 6: Example for detecting CWA with GC-MS
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Detection of other harmful substances

Table 2: Selected harmful substances other than narcotics and CWA, identification values by means of **IUT-IMS**

Compound	$\frac{T_M}{T_{RP}}$	$\frac{T_D}{T_{RP}}$	other	MDC in ppb	Ionisation
Acetic acid	1.06	1.17		10	β(+) (β(-)
Acetone	1.12			1	β(+)
Acetophenone	1.20	1.58		1	β(+)
Ammonia	0,90	0,85		1	β(+)
Arsine (with modified grid)	1.03	1.16		10	UV
Ethanol	1.06	1.15		10	β(+)
Methanol	0.97	1.03		20	β(+)
Benzene	0.96			5	UV
Carbon disulphide	0,96			5	β(-)
Chlorine	0,95			10	β(+)
Cyclohexane	1.04	1.09	1.13	50	β(+)
Diaminobutane	1.1	1.30		10	β(+)
Diaminobutane	1.34	1.75		10	β(-)
Diborane	0,94			10	β(-)
Dimethylformamide	1.04	1.26		1	β(+)
Diethylether	1.08	1.25		1	β(+)
Dichlorethane	0.91	0.98		5	β(-)
Ethylacetate	1.11	1.36		1	β(+)
Ethylmethylketone	1.07	1.27		1	β(+)
Formaldehyde	0.99			10	β(+)
Hydrazine	1.04	1.14		10	β(-)
Hydrochloric acid	0,91			25	β(-)
Hydrogen sulphide	0,85			10	β(-)
Isooctane	1.03	1.11	1.16	50	β(+)
Nicotine	1.38	2.12		2	β(+)
Nitrobenzene	1.26	1.55		10	β(-)
Nitric oxide	1,07			50	β(+)
Nitrogen dioxide	0,90			1000	β(+)
Phenol	1.27			10	β(-)
Phosphine	n/a			n/a	n/a
Phthalic acid dibutylester	1.19	1.40		1	β(+)
Pyridine	1.02	1.27		10	β(+)
Toluene	1.02			5	UV
Trichlorethylene	0.93	0.96	1.44		β(-)
Trichlorfluoromethane	0.97	1.03			β(-)
Tricresylphosphate	1.69	2.49		3	β(+)

Substanzliste ALLGEMEIN (Industrie- und Umweltgifte)

Remarks:
1) About 200 chemical compounds are measured at I.U.T. Ltd.
   The spectra are available here.
2) Any other compound may be measured in the I.U.T.-laboratory.

Compound	$\frac{T_M}{T_{RP}}$	$\frac{T_D}{T_{RP}}$	other	MDC in ppb	Ionization
Alcohols					
Butanol	1.19	1.41	1.68	10	β(+)
Cresol	1.14			10	β(+)
Cyclohexanol	1.28	1.35	1.58	10	β(+)
Ethanol	1.06	1.15		10	β(+)
Heptanol	1.42	1.81		10	β(+)
Methanol	0.97	1.03		20	β(+)
Tetrahydrofurfurylalcohol	1.16	1.43		10	β(+)
Alcanes					
Cyclohexane	1.04	1.09	1.13	50	β(+)
Heptane	1.12			50	β(+)
Isooctane	1.03	1.11	1.16	50	β(+)
Nonane	1.55			50	β(+)
Aldehyde					
Butylaldehyde	1.13	1.22	1.30	10	β(+)
Formaldehyde	0.99			10	β(+)
Heptylaldehyde	1.35	1.72		10	β(+)
Propionaldehyde	1.04	1.16	1.33	10	β(+)
Amines					
Amphetamine	1.13	1.67		1	β(+)
Diaminobutane	1.1	1.30		10	β(+)
Diaminobutane	1.34	1.75		10	β(-)
Diaminopropane	1.26			10	β(+)
Diaminopropane	1.34	1.75	0.93	10	β(-)
Dimethylformamide	1.04	1.26		1	β(+)
1,1-Dimethylhydrazine	1.24			1	β(+)
Dimethylurea	0.91	0.94	1.10	1	β(+)
Hexamethylentetramine	0.96	1.17		10	β(+)
Hexylamine	1.21	1.60	0.92	1	β(+)
Hydrazine	1.04	1.14		10	β(-)
Methylhydrazine	1.24			1	β(-)
Methylhydrazine	0.85	0.92	1.05	1	β(+)
Nicotine	1.38	2.12		2	β(+)
Nonafluorobutylamine	1.44			1	β(-)
Aromates					
Benzene	0.96			5	UV
Chlorophenol	1.33	1.69		10	β(-)
Cumene	1.15	1.17		5	UV
Dimethoxybenzene	1.16	1.29	1.61	10	β(+)
Ethylbenzene	1.20	1.60		5	β(+)
Iodobenzene	0.95			10	β(-)
Nitrobenzene	1.26	1.55		10	β(-)
Phenol	1.27			10	β(-)
p-Xylene	1.08			5	UV
Toluene	1.02			5	UV

Compound	$\frac{T_M}{T_{RP}}$	$\frac{T_D}{T_{RP}}$	other	MDC in ppb	Ionization
Carbon acids					
Acetic acid	1.06	1.17		10	β(+) (β(-)
Formic acid	1.13	1.20			β(-)
Esters					
Ammoniumacetate	0.85	0.91	0.95	1	β(+)
Ethylacetate	1.11	1.36		1	β(+)
Ethylacetoacetate	1.18	1.39	1.62	1	β(+)
Phthalic acid diethylester	1.05	1.15		1	β(+)
Phthalic acid dibutylester	1.19	1.40		1	β(+)
Phthalic acid dioctylester	1.11	1.28	1.36	1	β(+)
Ethers					
Diethylether	1.08	1.25		1	β(+)
Divinylether	1.20	1.69	1.75	1	β(+)
Halogenated Hydrocarbons					
Amylchloride	0.91	0.98	1.04		β(-)
Amylchloride	1.29	1.75			β(+)
Chlorbromomethane	0.93	1.03	1.50		β(-)
Chloroacetonitrile	0.91	0.98	1.14		β(-)
Chlorotrimethylsilane	1.21	1.36			β(-)
Dichlorethane	0.91	0.98		5	β(-)
Dibromethane	0.93	0.96	1.05		β(-)
Dibromobutane	0.93	0.96	1.05		β(-)
Dibromomethane	0.93	0.96	1.05		β(-)
Dibromopropane	0.93	0.96	1.05		β(-)
Isobutylchloride	0.91	0.96	1.34		β(-)
n-Butylchloride	0.91	0.98	1.04		β(-)
Methylchlorid	0.82			1000	β(-)
Trichlorethylene	0.93	0.96	1.44		β(-)
Trichlorfluoromethane	0.97	1.03			β(-)
Vinylchloride (VC)	1.20			100	β(+)
Ketons					
Acetone	1.12			1	β(+)
Acetophenone	1.20	1.58		1	β(+)
Acetylacetone	1.12	1.44	1.46		β(+)
Acetylacetone	1.05	1.26			β(-)
Benzophenone	1.36	1.95			β(+)
Ethylmethylketone	1.07	1.27		1	β(+)
Hexanone	1.21	1.53			β(+)
Phosphororganic compounds					
Malathion	1.13	1.37			β(+)
Tributylphosphite	1.19	1.41	1.56	1	β(+)
Tricresylphosphate	1.69	2.49		3	β(+)
Pyridine					
Pyridine	1.02	1.27		10	β(+)
2-Dimethylpyridine	1.67	1.40		10	β(+)

Compound	$\frac{T_M}{T_{RP}}$	$\frac{T_D}{T_{RP}}$	other	MDC in ppb	Ionization
Others					
Acroleine	1,13				β(+)
Ammonia	0,90	0,85		1	β(+)
Arsine (with modified grid)	1.03	1.16		10	UV
Dibutylsulfite	1.32	1.84			β(+)
Carbon disulfide	0,96			5	β(-)
Chlorine	0,95			10	β(+)
Diborane	0,94			10	β(-)
Hydrochloric acid	0,91			25	β(-)
Hydrocyanic acid	0,92			5	β(-)
Hydrogen sulfide	0,85			10	β(-)
Nitric oxide	1,07			50	β(+)
Nitrogen dioxide	0,90			1000	β(+)
Nitrogen dioxide	0,93	0,98		1000	β(-)
Phosgene low[1]	0,87	0,96		0,5	β(-)
high				100	
Phosphine*	n/a			n/a	n/a
Sulfur dioxide	1,03			10	β(-)
Sulfur hexafluoride	1,13			10	β(+)
tert-Dibutylmalonate	1.04	1.27			β(+)

[1] = the new model of GC-IMS allows to change between the measuring ranges **low** (0-100 ppb) and **high** (0-100 ppm).

* = Phosphine can be measured with the I.U.T.-Photo Ionisation Detector (PID)