G8 GALILEO
G4 PHOENIX

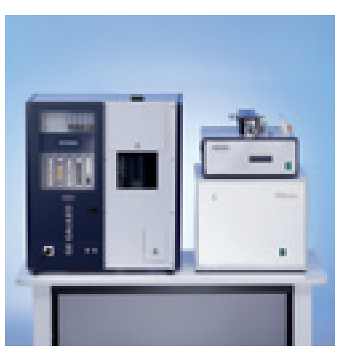
- Solutions for Inert Gas Fusion Analysis of Inorganics

Elemental Analysis

Innovation with Integrity

*) Best H_2 detection limit in an ONH system using a thermal conductivity detector with a dedicated reference channel. Uniquely coupled infrared furnace for diffusible hydrogen applications. Uniquely coupled mass spectrometer for ultra-low concentrations of hydrogen and argon with highest selectivity.


G8 GALILEO


G8 GALILEO MS


G4 PHOENIX


G4 PHOENIX MS

Control the World of Metals with Just a Few Elements

Ores, metals, alloys and ceramics shape our time.

For thousands of years, metals and alloys have played a prominent role in the evolutionary history of humanity and give names to entire epochs.

The three non-metals Oxygen (O), Nitrogen (N) and Hydrogen (H) determine the quality, service life and mechanical properties of all metallic materials. Unlike metallic alloy components, the amount of O, N and H sometimes changes considerably along the entire process chain, from the production of raw materials to the completion of the finished product.

Light elements make heavy work.

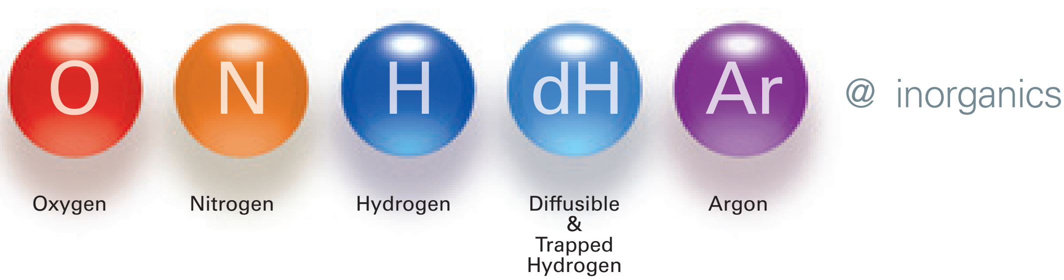
Even when present in trace amounts, O, N and H have a very critical effect on the material properties. However, low concentrations are difficult to analyze with spectroscopic methods due to the atomic properties of O, N and H. So what can be done? Use the best method: Inert Gas Fusion Analysis. No other method provides better detection limits, reliability or stability.

Match the best ONH method, with the ideal ONH systems: G8 GALILEO and G8 GALILEO MS.

With the G8 GALILEO analyzers, Bruker is the only company to offer fully integrated ONH solutions combining the benefits of multiple dedicated systems without any analytical compromise or technical limitations![*)]

G4 PHOENIX and G4 PHOENIX MS – experts for the first element: hydrogen.

The accurate analysis of mobile hydrogen is extremely important in many areas. Bruker offers extremely powerful systems for the analysis of diffusible and trapped hydrogen: G4 PHOENIX and G4 PHOENIX MS.



G8 GALILEO with Smart Molecule Sequence™ for Direct Measurement and Real 1:1 Information

The G8 GALILEO with Smart Molecule Sequence™ guarantees proven science and trustworthy results.

Why is the G8 GALILEO superior to other ONH systems?

- The G8 GALILEO performs direct and unadulterated measurements of all gases emitted by the sample, in a 1:1 ratio – without chemical transformation, repetitive measurements, mathematical corrections or unpublished algorithms.
- The G8 GALILEO offers all possibilities of a state-of-the-art solution for O, N and H in one system, without analytical compromise.
- The G8 GALILEO can measure even lowest hydrogen concentrations in the ng/g (ppb) range directly and reliably, without compromises.
- The G8 GALILEO detects the exact temperature of the sample directly with FusionControl and thus ensures that only the measured gases (CO, N_2 and H_2) are formed – no CH_4, no other hydrocarbons.

What are the advantages of Smart Molecule Sequence™?

- Each of the three elements O, N and H is analyzed 1:1, where the concentration of $CO \triangleq O$, $N_2 \triangleq N$ and $H_2 \triangleq H$.
- Nitrogen or argon can be used as an alternative carrier gas, instead of the standard, but expensive and rare carrier gas helium.
- Not only nitrogen, but hydrogen as well is measured using a highly sensitive DualChannel Thermal Conductivity Detector (TCD) with a separate reference channel. Comparison of the measurement channel with the reference channel ensures scientifically proven analyses. The unique combination with a heat exchanger guarantees exactly the same temperature of reference and analysis gases.
- Smart test setup and exact temperature control result in less dust, offer system stability and higher uptime.

**G8 GALILEO –
ONH Analysis @ its best!**

FusionControl for real-time sample temperature detection, Bruker only

DualChannel TCD with integrated heat exchanger for identical temperature of reference and analysis gases

Unique gas calibration unit for standardless hydrogen calibration with 10 independent volumes

O, N, H
@ its best

O N H @ its best

G8 GALILEO – for direct measurement of emitted gasses – 1:1 Oxygen, 1:1 Nitrogen and 1:1 Hydrogen

Highly flexible sample changer and integrated crucible changer.

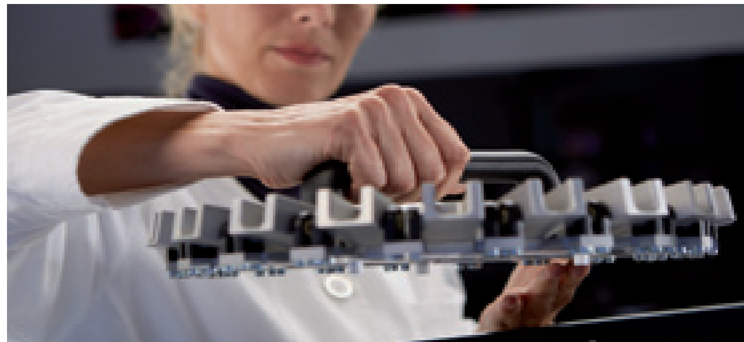
- Sample changer with 20 or 40 positions.
- Optional independent aggregate feed, with 20 samples plus 20 flux additives, important for the measurement of hydrogen in titanium alloys with nitrogen carrier gas.
- Removable sample plates with robust, failure proof sample containers.
- Sample containers can even be easily filled with chips.
- Integrated crucible waste container monitoring.

Fully automatic furnace cleaning.

- Cleans upper and lower furnace electrodes at freely programmable intervals.
- Cleaning unit is safely placed behind a glass pane.
- Advantage: no intervention, no adjustment, maximum safety and cleanliness.

Advanced electrode furnace with sample port.

- Maintenance-free and reliable sample port without consumable parts.
- No jamming due to O-ring sealed slider.
- The sample port integrated into the water-cooled furnace protects the sample from undesirable heating during crucible outgassing.
- Different sample port inserts available for different sample types and crucibles.
- Upper and lower furnace electrodes can be replaced easily and separately.
- Time savings and more stable results through sequential analysis of up to five samples (depending on material) in the same crucible without prior outgassing or opening the furnace.
- Ongoing, contact-free temperature measurement of the sample via FusionControl, Bruker only.



20 position sample tray with failsafe sample chutes

Simultaneous cleaning of both electrodes

Fully automated crucible handling

Monitored waste bin for crucibles

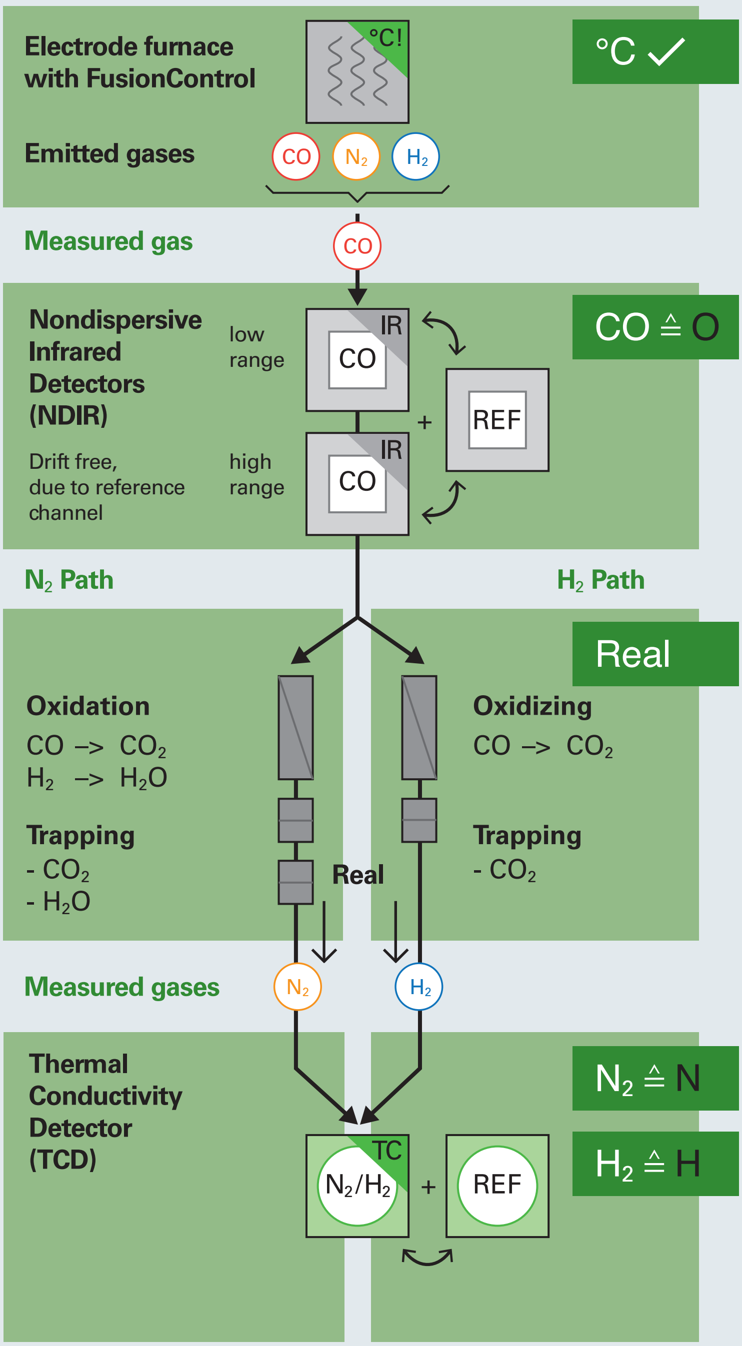
O N H @ high throughput

G8 GALILEO with 40 position autosampler for ONH analysis @ high throughput

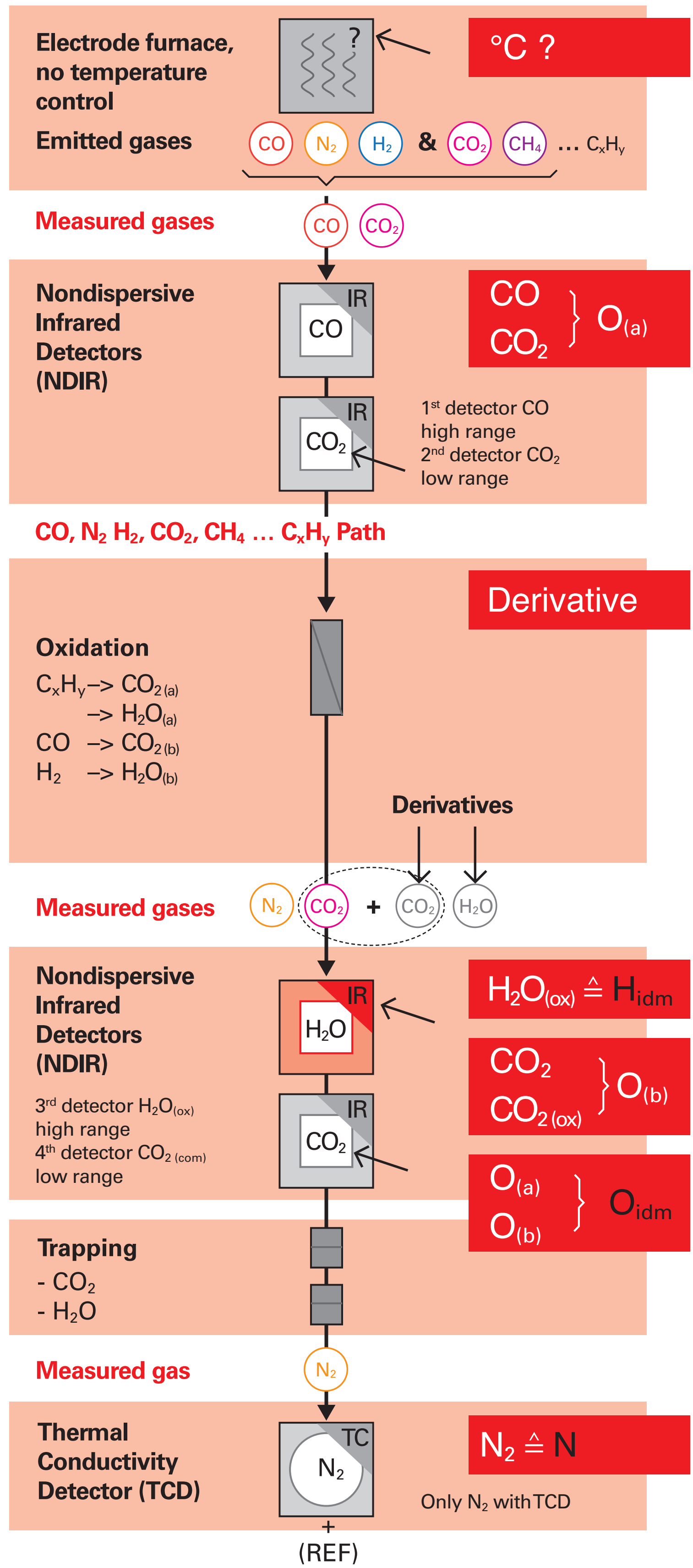
G8 GALILEO with Smart Molecule Sequence™ for Direct 1:1 Measurement

VS.

Conventional Systems with Simultaneous Setup and Indirect Measurement



Emitted = Measured
1:1 Oxygen
1:1 Nitrogen
1:1 Hydrogen



We keep it simple and measure real sample gases!

The aim is to determine the sample content of the three light elements O, N and H in the trace range with absolute accuracy. That's why our G8 GALILEO measures CO, N_2 and H_2 directly, absolutely unchanged, 1:1, and with ideal detection techniques. Thanks to direct temperature control of the sample, no hydrocarbons and interfering CO_2 are produced at all. To us, ONH analysis must be simple or it's simply not accurate.

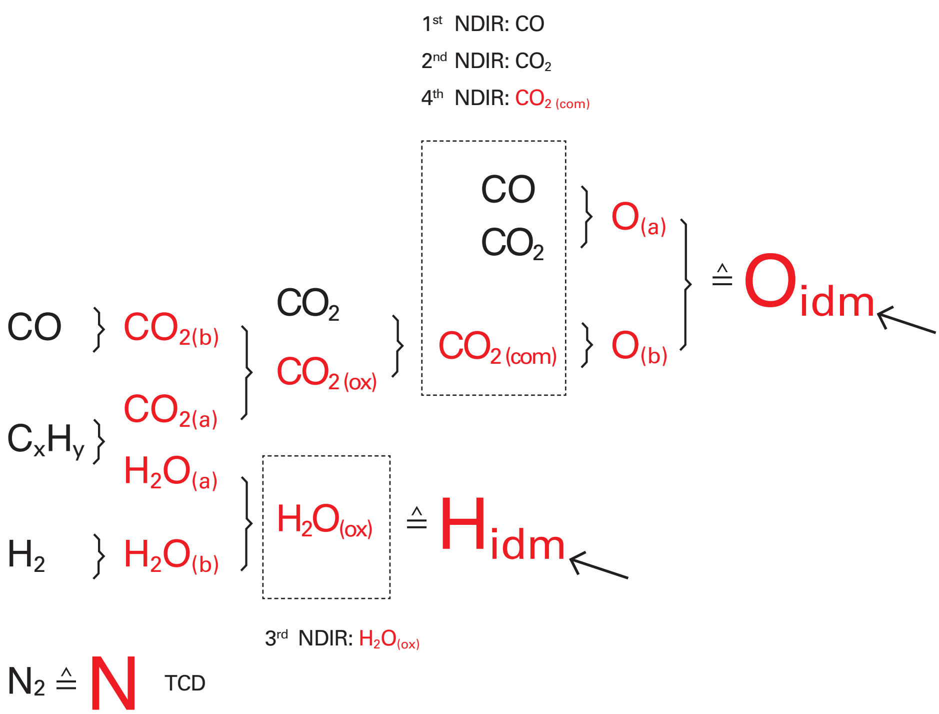
1:1

$CO \triangleq O$ 2 × NDIR

$N_2 \triangleq N$ TCD

$H_2 \triangleq H$ TCD

VS.



Others make it complicated and measure derivatives.

If the gases emitted by the sample must be chemically transformed into derivatives to analyze them, this is called indirect measurement (idm). Measurement errors add up and standard deviations increase, in particular in the case of multiple transformations, when different measurements are combined and when the measuring molecules are generated from different origins. Conclusion: indirect measurement is more complicated.

Determining the hydrogen content via water vapor has several disadvantages:

- Water must be kept permanently in the gas phase.
- Water can only be measured with insufficient sensitivity by IR detection.
- In the IR spectrum, water interferes with CO_2, which needs to be mathematically corrected.

G8 GALILEO with Smart Molecule Sequence™ for Direct 1:1 Measurement

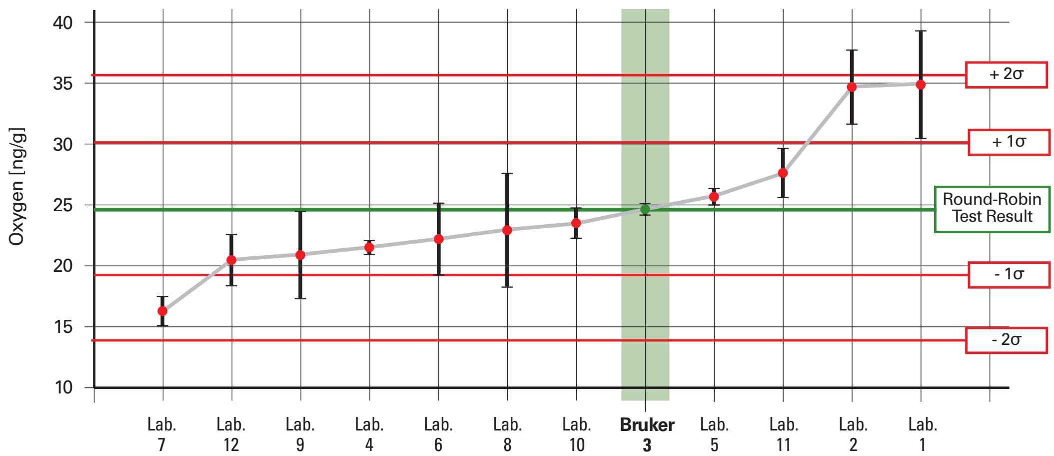
VS.

Conventional Systems with Simultaneous Setup and Indirect Measurement

G8 GALILEO		Conventional Systems
Yes	Temperature Control	**No**
Electrode furnace with FusionControl (°C!)		**Electrode furnace, no sample temperature control** (°C ?)
Emitted gases CO, N_2, H_2		**Emitted gases** CO, N_2, H_2 & CO_2, CH_4 … C_xH_y
Yes	no CO_2, no CH_4, no C_XH_Y	**No**
CO, N_2, H_2 no CO_2, CH_4 … C_xH_y		CO, N_2, H_2 & CO_2, CH_4 … C_xH_y
Nondispersive Infrared Detectors (NDIR) CO is measured with two detector ranges. The molecules from the sample remain untouched **1:1 Oxygen** IR CO + REF, IR CO CO matched to low range CO matched to high range		**Nondispersive Infrared Detectors (NDIR)** The first oxygen value ($O_{(a)}$) is calculated from the measurement of CO and CO_2, one detector for each molecule IR CO, IR CO_2 CO all range CO_2 low range
CO ≙ O **Yes**	All Oxygen at Once	**No** CO, CO_2 } $O_{(a)}$
Oxygen? Done! O ✓		**Oxygen? Not yet!** $O_{(a)}$ …
CO, N_2, H_2		CO, N_2, H_2 & CO_2, CH_4 … C_xH_y

Oxygen performance @ its best

Oxygen: Average Value / Laboratory, Round-Robin Test “Oxygen in Copper”*)



The whole round-robin test certificate is of course available on request.

Accuracy doesn’t Come by Chance – Round-Robin Test “Oxygen in Copper”*)

Basic Questions:

- Should the sample temperature be monitored?
- Does the direct measurement of CO provide better results?
- Does every chemical conversion lead to greater uncertainties?
- Should the formation of hydrocarbons be prevented?

The answer to these questions is yes, four times over. The system combining all of these advantages is the G8 GALILEO.

The result of the “Analytical Determination of Oxygen in Copper” round-robin test supervised by the German Federal Institute for Materials Research and Testing shows that Bruker's system delivers excellent results, both in terms of accuracy and in terms of reproducibility.

Why did the G8 GALILEO perform so well?

- FusionControl in the G8 GALILEO prevents the formation of hydrocarbons and other undesirable byproducts that result from excessively high sample temperatures. Thanks to FusionControl’s exact sample temperature control, the traditional approach of heating up the sample as high as possible is no longer necessary.
- With the G8 GALILEO the carbon monoxide emitted by the sample is measured directly and in a 1:1 ratio.
- Unlike the G8 GALILEO, conventional systems increase the measurement error by additional oxidation steps and multiple measurements of different molecules.

Conclusion: The smarter and simpler the setup, the more reliable the results, especially at low concentration ranges and tight tolerances.

*) “Analytical Determination of Oxygen in Copper” round-robin test by the “Special Materials” working committee in the Chemists Committee of the Society for Mining, Metallurgy, Raw Materials and Environmental Technology (GDMB) under supervision of the German Federal Institute for Materials Research and Testing.

G8 GALILEO with Smart Molecule Sequence™ for Direct 1:1 Measurement

VS.

Conventional Systems with Simultaneous Setup and Indirect Measurement

Use Emitted Gases Only

G8 GALILEO: Yes — **Conventional: No**

Emitted gases (G8 GALILEO): CO, N_2, H_2

Emitted gases (Conventional): CO, N_2, H_2 & CO_2, CH_4 … C_xH_y

Smart Molecule Sequence™

N_2 Path
He or Ar Carrier Gas

H_2 Path
N_2 or Ar Carrier Gas

Simultaneous Setup

CO, N_2 H_2, CO_2, CH_4 … C_xH_y Path
He Carrier Gas

No Derivatives

G8 GALILEO: Yes — **Conventional: No**

G8 GALILEO – N_2 Path

remove: CO, H_2 — from sample: N_2

Oxidation

CO –> CO_2
H_2 –> H_2O

Trapping

- CO_2
- H_2O

N_2

measure: N_2

G8 GALILEO – H_2 Path

remove: CO — from sample: H_2

Oxidation

CO –> CO_2

Trapping

- CO_2

H_2

measure: H_2

All molecules are measured unchanged as emitted from the sample – real 1:1 measurement

Origin of CO

1. Sample

Origin of N_2

1. Sample

Origin of H_2

1. Sample

Conventional Systems

change: CO, H_2, CH_4 … C_xH_y — from sample: CO_2, N_2

Oxidation

C_xH_y –> $CO_{2\,(a)}$
–> $H_2O_{(a)}$
CO –> $CO_{2\,(b)}$
H_2 –> $H_2O_{(b)}$

from oxidation: $H_2O_{(ox)}$ $CO_{2\,(ox)}$

from sample: CO_2 N_2

measure: N_2, CO_2 + CO_2, H_2O

Origin of CO_2

1. Oxidizing CO
2. Oxidizing CH_4 … C_xH_y
3. Sample

Origin of N_2

1. Sample

Origin of H_2O

1. Oxidizing H_2
2. Oxidizing CH_4 … C_xH_y

Derivatives

$H_2O_{(a)}$, $H_2O_{(b)}$ } $H_2O_{(ox)}$

$CO_{2(a)}$, $CO_{2(b)}$ } $CO_{2(ox)}$

Melting Points and Emitted Gases [°C]

There is no temperature equally suited for measuring O, N and H. As a matter of principle and also with respect to sample preparation, simultaneous systems cannot work optimally for each of the elements at the same time.

To get Real Information, you Have to Measure Real Gases – Directly, Unchanged – 1:1

At first glance, a simultaneous ONH measurement seems to be a fast and cost-effective solution. Rather, in fact, existing simultaneous systems have to deal with a number of fundamental problems.

Instead of directly measuring the molecules emitted by the sample, the sample gases must be elaborately processed and so derivatives are generated. Ultimately, CO_2 and H_2O are measured from multiple sources.

The oxygen content is calculated using proprietary mathematical processing of different measured values.

Water vapor measurements are particularly difficult with simultaneous systems:

- The gas tubing system must be permanently heated to prevent water vapor condensation.
- Water vapor is measured using an infrared detector. This analysis method is by principle not ideal for the trace analysis of water.
- Spectroscopic interferences during the IR measurement of CO_2 and H_2O must be compensated using complex mathematics, which are usually hidden.

Thanks to the Smart Molecule Sequence™, the G8 GALILEO measures each element directly, unchanged and under ideal conditions.

- CO is measured with two infrared detectors: one for the ng/g range, one for the % range.
- H_2 is determined down to the ng/g range with a highly sensitive thermal conductivity detector (TCD) with reference channel, a scientifically proven method.
- N_2 is analyzed with a highly sensitive TCD plus reference channel.
- In addition to helium, the G8 GALILEO can use different carrier gases, for example argon and nitrogen, right out of the box.
- Optimized gas flow in the ambient pressure system G8 GALILEO eliminates the need for complex and error-prone flow compensation. In overpressure systems flow compensation is necessary, so that high oxygen concentrations do not lead to incorrect nitrogen results.

G8 GALILEO with Smart Molecule Sequence™ for Direct 1:1 Measurement

VS.

Conventional Systems with Simultaneous Setup and Indirect Measurement

G8 GALILEO		Conventional Systems
Yes	Hydrogen but Water Vapor	No
Yes	H_2 @TCD, Real Referencing	No

Thermal Conductivity Detector (TCD)

All molecules remain untouched and are analyzed as emitted from the sample – one by one

1:1 Nitrogen
1:1 Hydrogen

both @TCD sensitivity

N_2 / H_2

+ reference channel

N_2, H_2 → TC N_2/H_2 + REF

$N_2 \triangleq N$

$H_2 \triangleq H$

G8 GALILEO		Conventional Systems
Yes	Real 1:1 Information	No

Nitrogen? Directly! N ✓

Hydrogen? Directly! H ✓

Bruker's Sequential Smart Molecule Sequence™ Allows a Direct 1:1 Measurement of Unchanged Emitted Gases!

Derivatives

N_2 CO_2 + CO_2 H_2O

Nondispersive Infrared Detector (NDIR)

For the second oxygen value (O_b), CO_2 from the sample plus $CO_{2\,(ox)}$ from oxidized CO and C_xH_y is measured as $CO_{2(com)}$

IR H_2O — $H_2O_{(ox)}$

H_2O measured with low sensitive NDIR

IR CO_2 — $CO_{2\,(com)}$

combined gas volume oxidation & sample

$CO_{2\,(com)} \triangleq O_{(b)}$

$H_2O_{(ox)} \triangleq H_{idm}$

Oxygen? Only mathematically generated. $O_{(a)}$, $O_{(b)}$ } O_{idm} ~

Hydrogen? Via water vapor and low sensitive NDIR. H_{idm} ~

Trapping
- CO_2
- H_2O

N_2

$N_2 \triangleq N$

Thermal Conductivity Detector (TCD)

TC N_2 + (REF)

Only the nitrogen molecule remains untouched

Only nitrogen is measured with a TCD. N ✓

Hydrogen performance @ its best

- H_2 measurement with highly sensitive TCD.
- Scientifically proven comparative measurement against reference channel.
- Heat exchanger for exact temperature matching of reference and analysis gas.
- Electronically adjustable measuring range of the TCD.

The G8 GALILEO analyzes the hydrogen content directly as H_2, using a highly sensitive TCD plus reference channel. This is necessary because the TCD measurement is a comparative method that needs to be permanently referenced to an independent channel. This reference channel ensures reproducible and accurate results, especially in the ng/g range.

The G8 GALILEO guarantees real measurement results for hydrogen, without unpublished algorithms.

Real H_2 Measurement with TCD Quality, Proven Science with Reference Channel

Comparison Nitrogen in Steel Carrier Gas Helium or Argon	Nitrogen Content	Deviation Helium	Deviation Argon
	[ng/g]	[ng/g]	[ng/g]
Sample A	19.7	± 0.33	± 0.34
Sample B	28.1	± 0.80	± 0.67
Sample C	95.4	± 1.19	± 1.21
Sample D	199.1	± 0.70	± 0.82
Sample E	11.8	± 0.46	± 0.46
Sample F	218.0	± 2.24	± 2.32

Nitrogen @ ease

- The same analytical quality without limitation for N_2 measurement with argon carrier gas.
- Measurement with argon carrier gas is significantly cheaper compared to helium.
- High supply reliability thanks to argon.

G8 GALILEO MS – Infrared Furnace for Diffusible Hydrogen & Mass Spectrometer for Utmost Sensitivity

Bruker's infrared furnace offers perfect temperature control with extremely slow or fast heating rates and cooling within minutes.

A furnace with precise temperature control directly at the sample is essential for the analysis of diffusible or trapped hydrogen. Conclusions about the nature of the hydrogen deposition in the metal structure can only be drawn by the exact correlation of the outgassing temperature to the hydrogen concentration.

Bruker's exclusive infrared furnace allows for extremely slow or fast heating rates. The water cooling system of the furnace ensures that it cools down within minutes. The system is calibrated using high-precision gas dosing.

The quartz furnace tube with its inner diameter of 30 mm is specifically sized for large samples, such as the 1-inch weld samples.

Highest sensitivity – down to a few parts per billion (ng/g) – is only offered by a mass spectrometer.

Mass spectrometry is widely recognized as an extremely sensitive method that can analyze particle densities down to a few molecules. However, in the traditional laboratory environment, mass spectrometers are mainly used to analyze heavy molecules and less for light elements or permanent gases.

With the G8 GALILEO MS, we offer the first industrial-grade mass spectrometer coupled to an inert gas fusion analyzer, tailor-made for the first element – hydrogen – and the determination of argon. Previously unknown small concentrations of hydrogen and argon can be routinely and easily analyzed thanks to the optimal combination of extremely efficient gas inlet system, performance-optimized ion source and highly sensitive detector.

As a matter of fact, it is built to last! The unique mass spectrometer is robust, maintenance-free and functionally reliable to suit the application environment.

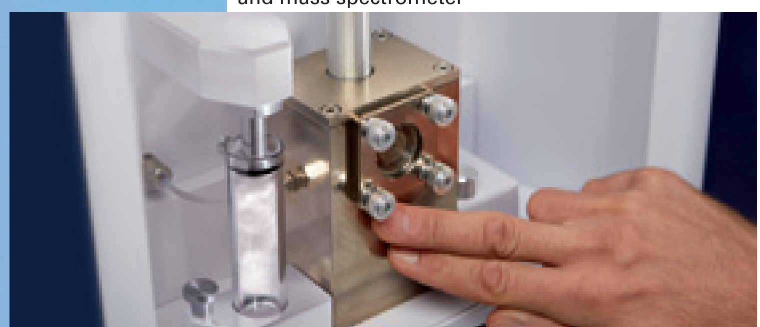
Bruker is the only company worldwide offering the smooth integration of an infrared furnace and/or mass spectrometer into an excellent ONH system.

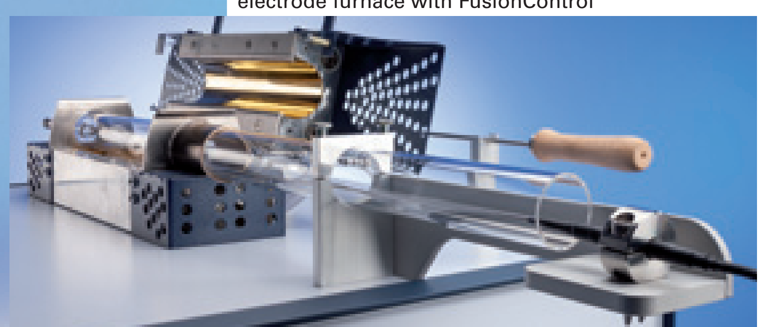
G8 GALILEO | G8 GALILEO MS | G8 GALILEO MS

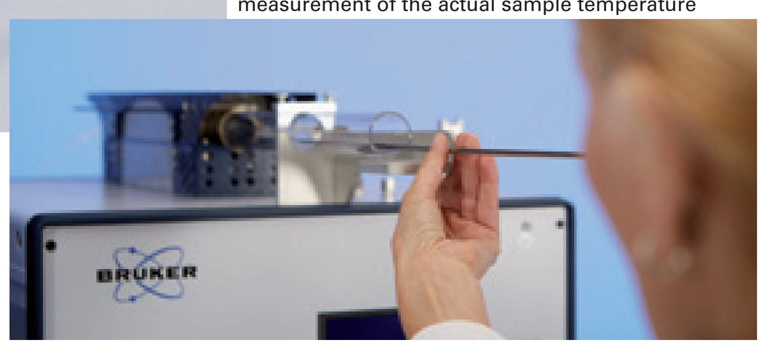
G8 GALILEO	G8 GALILEO MS	G8 GALILEO MS
O, N, H dH TDS	O, N, H Ar @ low ng/g	O, N, H dH & Ar @ low ng/g TDMS

dH Ar @ low ng/g (ppb)


G8 GALILEO MS with infrared furnace and mass spectrometer


Easily accessible particle filter, water-cooled electrode furnace with FusionControl

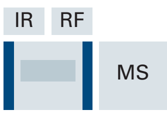

Infrared furnace with thermocouple for an accurate measurement of the actual sample temperature



Large diameter (Ø 30 mm) for 1-inch samples like used in AWS A4.3


G8 GALILEO MS for diffusible hydrogen and highest sensitivity

G4 PHOENIX MS



dH @ low ng/g
TDMS
≥ 1,100 °C

G8 GALILEO MS

O, N, H
dH & Ar @ low ng/g
TDMS
≥ 3,000 °C

@ low ng/g & TDMS

Don't Miss a Molecule – Thermal Desorption Mass Spectroscopy – Only from Bruker

High strength and low weight requirements make the analysis of diffusible and trapped hydrogen indispensable.

Applications of metallic materials in industry often require the properties of high strength and low weight. High-strength steels are increasingly used for modern assemblies, and highly complex stamped-bent designs are made from rolled sheets and strips. The original materials are rolled several times, thermally treated, galvanized, bent, stamped, welded or coated during the production process. The risk of penetration and inclusion of reactive, atomic hydrogen occurring in all environments increases with every production step. Even the smallest amount of hydrogen can lead to hydrogen embrittlement during recombination and finally to component failure.

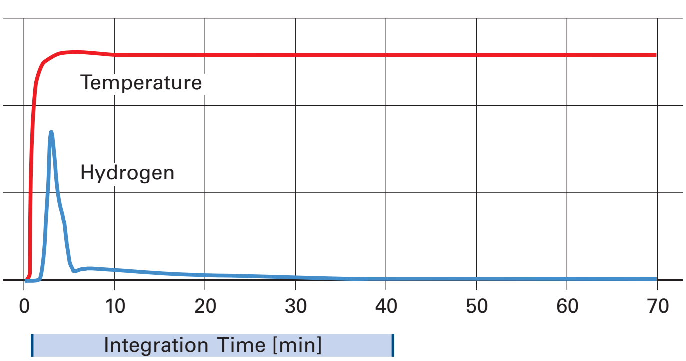
Using long-term measurements and temperature profiles, Thermal Desorption Mass Spectroscopy (TDMS) gives you information about the type of hydrogen inclusions within a metal structure.

The type of hydrogen inclusion – diffusible, weakly or strongly trapped, or chemically bound – can be directly correlated with the supplied activation energy and leads to different peaks during the hydrogen measurement using temperature profiles.

To ensure that long-term measurements of a few molecules are reliable, perfect temperature control using an infrared or resistance furnace (depending on the material) and a highly sensitive detector is required. Unique to Bruker's G8 GALILEO MS, however, is the use of a mass spectrometer for the trace analysis of hydrogen at concentrations of a few ng/g.

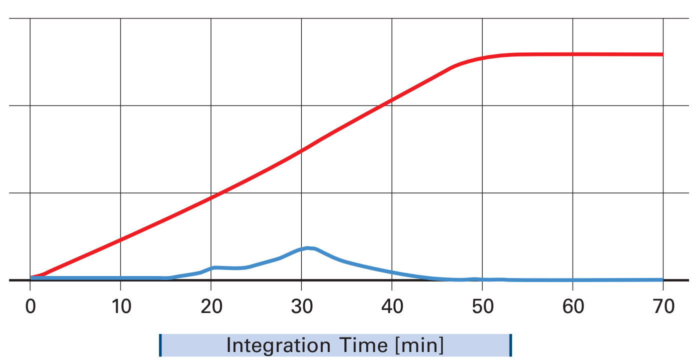
Highly sensitive hydrogen analysis using TDMS is only available from Bruker.

Hydrogen Detection with Constant Temperature



680 ng/g Hydrogen

Hydrogen Detection with Temperature Ramp



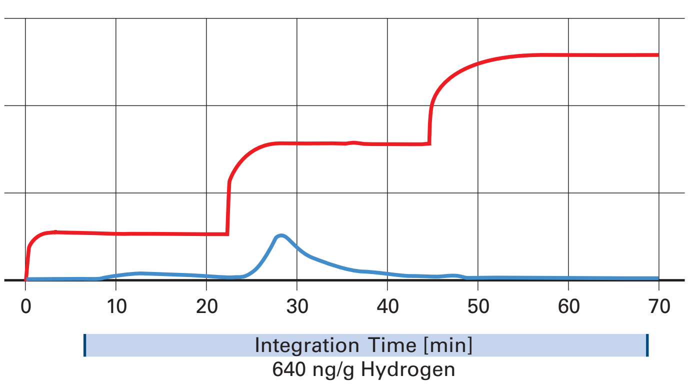
620 ng/g Hydrogen

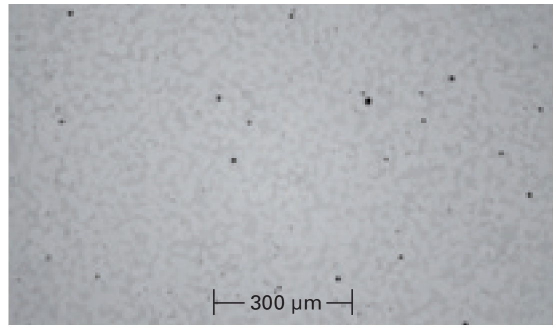
O, N, H
Ar @ low ng/g

Argon is the Element to Analyze when it comes to HIP and Additive Manufacturing

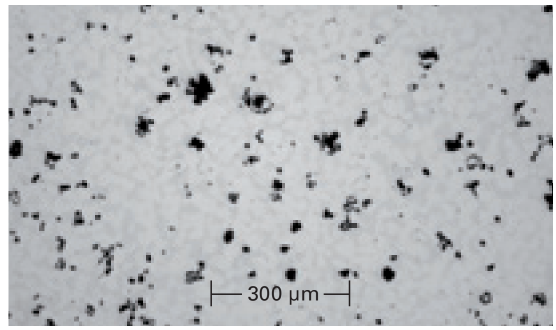
@ low ng/g

Hydrogen Detection with Temperature Steps





Metal structure without heat treatment,
argon content: 16,177 ng/g



Metal structure after heat treatment, leading to pore expansion due to argon gas expansion,
argon content: 16,177 ng/g

State-of-the-art production processes, such as Hot Isostatic Pressing (HIP), and additive manufacturing require high-precision argon analysis.

Compared to classical casting, forging, and machining processes, HIP and 3D printing offer many technical and commercial advantages. The objective of modern processes is to produce a metal structure that is as homogeneous and pore-free as possible, even for complex component geometries. The use of the inert gas argon is characteristic of these production processes. However, argon is not only used during component production, but also in the atomization process during metal powder production. As argon inclusions in the trace range can lead to material failure of the component, the argon content of process gases, metal powders, and final products must be continuously monitored.

Argon analysis? Only possible with the G8 GALILEO MS for concentrations of a few ng/g!

With the G8 GALILEO MS, Bruker is the only manufacturer worldwide offering a system for the reliable and high-precision analysis of argon concentrations of a few ng/g. Only the G8 GALILEO MS can determine whether the residual pores of a component contain argon or other process gases. Other measuring methods, such as optical microscopy or computer tomography, fall short. The G8 GALILEO MS, of course, can also be used as an ONH analyzer.

Process Gases

Carrier Gas:
Nitrogen, Helium, Argon

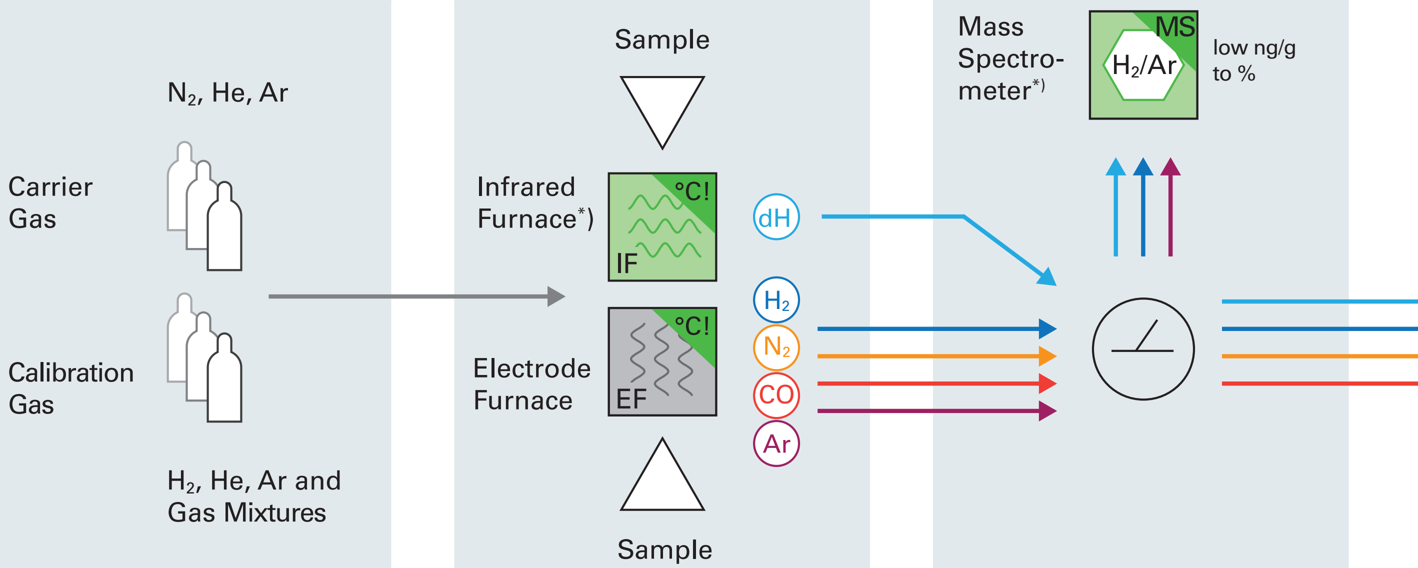
Calibration Gas:
Helium, Hydrogen, Argon
and Gas Mixtures

Infrared & Electrode Furnace

FusionControl

Mass Spectrometer

low ng/g to %



- Easy switching between different carrier and calibration gases.
- N_2 measurement with argon carrier gas: same analytical quality, without restriction, more affordable and greater supply reliability.
- Unique gas calibration unit for standardless hydrogen calibration with 10 independent volumes.

- Water-cooled electrode furnace, optionally with 20- or 40-position autosampler, automatic electrode cleaning and automatic crucible changer.
- Precise temperature control of the sample with FusionControl – exclusively from Bruker.
- Additional infrared furnace*) for diffusible hydrogen up to 900 °C – exclusively from Bruker.
- Easy accessibility and innovative design for high reliability, maximum uptime and low service costs.

- Industrial-grade mass spectrometer tailor-made for hydrogen and argon.
- Detection limits in the lower ng/g range, particle density of a few molecules.
- State-of-the-art combination of extremely efficient gas inlet system, performance-optimized ion source and high-sensitivity detector.

*) Option

Nondispersive Infrared Detectors (NDIR)

O

ng/g to %

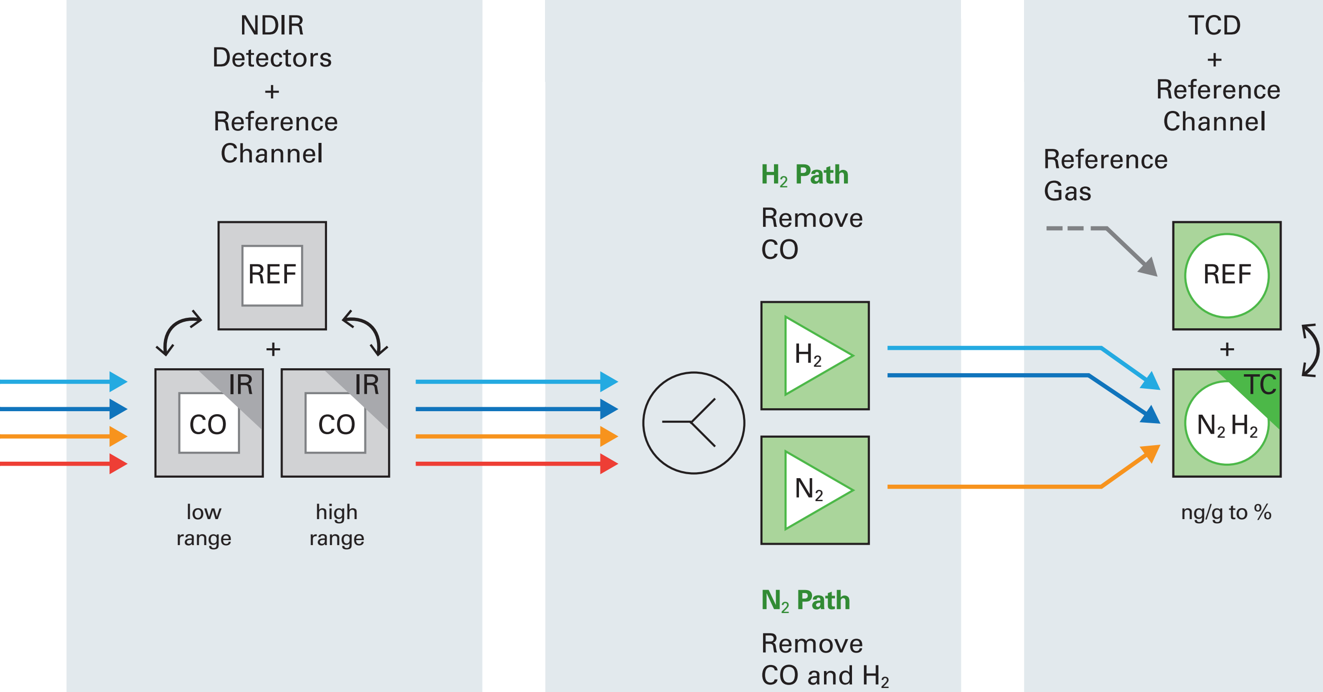
Smart Molecule Sequence™

Emitted = Measured
1:1 Oxygen
1:1 Nitrogen
1:1 Hydrogen

Thermal Conductivity Detector (TCD)

dH H N

ng/g to %

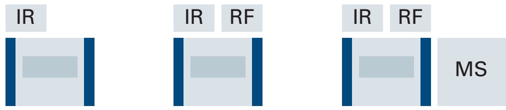


- Two powerful NDIR detectors*), one each for low (ng/g) and high oxygen content (%).
- Powerful NDIR detector with electronic range selection.
- Drift free, due to reference channel.
- Reliable, no moving parts, and mature detector technology.

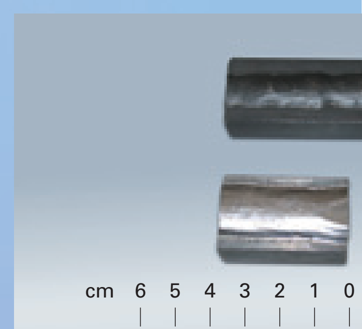
- 1:1 analysis of emitted sample gases, unchanged.
- Measurement for each element with optimal temperature and optimized sample preparation.
- No disruptive CO_2, no unwanted hydrocarbons.
- No multiple measurements, no oxidation, no conversion.
- No mathematical corrections, no unpublished algorithms.

- Scientifically proven comparative measurement against reference channel.
- Heat exchanger for exactly the same temperature of reference and analysis gas.
- Electronically optimizable measuring range of the TCD.
- N_2 measurement with argon without restrictions.
- H_2 measurement also with highly sensitive TCD.

G4 PHOENIX	G4 PHOENIX	G4 PHOENIX MS

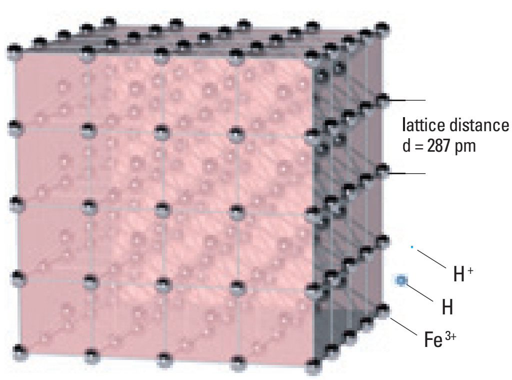


dH TDS ≥ 900 °C	dH TDS ≥ 1,100 °C	dH @ low ng/g TDMS ≥ 1,100 °C



G4 PHOENIX with infrared furnace (≥ 900 °C) and resistance furnace (≥ 1,100 °C)

Metal Lattice

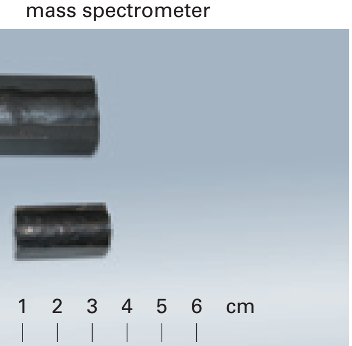


Ionic Radius [pm]			Covalent Radius [pm]			Molecule Radius [pm]		
H^+		**0.00087**	H		37	H_2		202
Fe^{3+}		63	Fe		125	–	–	–
Li^+		73	Li		134	–	–	–

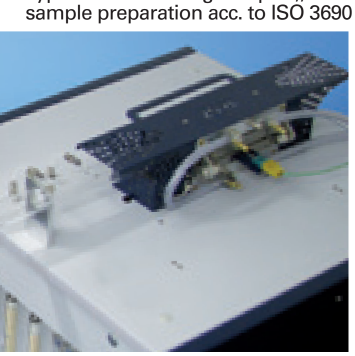
@ low ng/g & TD(M)S

G4 PHOENIX MS – The One and Only Solution for Only One Task: Diffusible Hydrogen @ its Best!


G4 PHOENIX MS with mass spectrometer



Typical steel welding samples,, sample preparation acc. to ISO 3690


Large diameter (Ø 30 mm) for typically 1-inch samples like used in AWS A4.3

Hydrogen: its properties and mechanisms of action are very remarkable and the subject of many current research studies worldwide – keyword: hydrogen embrittlement.

Hydrogen is the most common element in nature, the lightest element in the periodic table, and has the smallest atomic diameter. Because of its small size, hydrogen diffuses effortlessly through any metal lattice. The challenging aspect about diffusible hydrogen is that it collects within the defects in the metal lattice and recombines at that location to form much larger hydrogen molecules. This results in an internal pressure increase within the material, which ultimately leads to weak points, cracks and material failure.

High-strength steels and oxygenated copper grades are particularly susceptible to hydrogen embrittlement. There is a risk of introducing hydrogen in every mechanical, thermal and galvanic manufacturing step, especially during welding and soldering.

There is no better commercially available method for the analysis of diffusible hydrogen other than carrier gas warm extraction, and no better system than Bruker's G4 PHOENIX MS.

For the analysis of diffusible hydrogen, an analyzer needs highest accuracy, extremely low detection limits, and very precise temperature control.

The G4 PHOENIX offers one perfect solution for all three of these requirements:

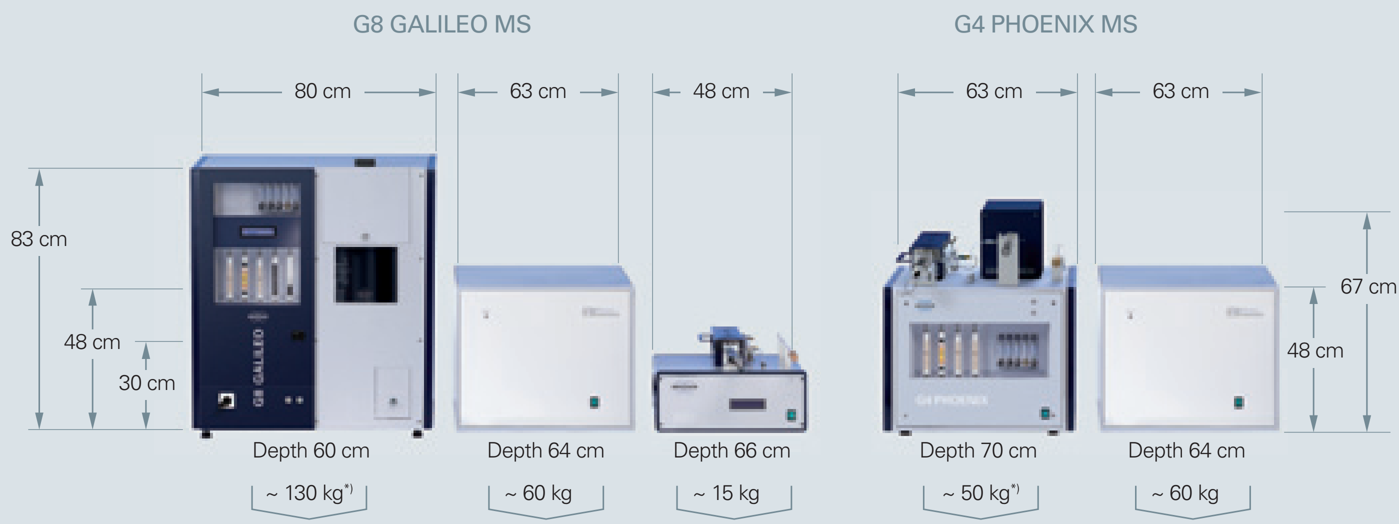
- The G4 PHOENIX comes equipped with a highly sensitive thermal conductivity detector, for the analysis of hydrogen down to the ng/g range, and an infrared furnace for accurate temperature control, very fast or very slow heating rates, rapid cooling, and for temperatures up to 900 °C.
- The system is optionally equipped with an additional resistance furnace for higher temperatures, up to 1,100 °C.
- The G4 PHOENIX MS with mass spectrometer offers the ultimate solution in terms of detection limits. It allows for hydrogen measurements with detection limits in the lower ng/g range down to a particle density of a few molecules.

Thermal Desorption Mass Spectroscopy (TDMS) also detects the type of hydrogen deposition.

Temperature ramps and long-term experiments in relation to the amount of hydrogen released enable conclusions about the type of deposition and ultimately about the type of material defects. The findings from these experiments provide important information for process and material optimization.

Overview of Features and Benefits

	Specification	Benefit
Detectors Oxygen	Nondispersive IR absorption of CO, no moving parts, dual-range detectors with reference beam and on-board linearization	Reliable, maintenance-free performance without drift
Nitrogen and Hydrogen	Thermal conductivity detector with reference channel and adjustable gain amplifier	Reliable, adjustable ranges, drift free
Argon and Hydrogen	Mass spectrometer 1-100 amu, single quadrupole, optimized EI source and channeltron detector	Unique mass spectrometry performance, sensitivity: a few molecules
Carrier Gases	He (O, N), Ar (O, N), N_2 (H) each 99.995 % purity (99.9990 % for trace analysis)	Flexible carrier gas choice without compromises
Calibration Gas	Pure gases or certified mixtures (99.999 % for each compound), 10 individual volumes in the gas dose device to cover a huge range	Easy, precise gas calibration without standards, directly tracable to fundamental parameters (pressure, temperature, volume)
Sample Dimensions	Electrode Furnace: 8 x 8 mm cross section (pieces, chips, pins, granules), sample ports available for special applications	
Cooling Water	Electrode Furnace: 4 l/min at 3 bar supply pressure IR Furnace: 1 l/min at 3 bar supply pressure, 15 – 20 °C inlet temperature, 100 – 240 V / 50 – 60 Hz	Fits on every usual tap water line, tap water-saving design with solenoid valve, chiller also possible
Power Supply G8 GALILEO	400 – 480 VAC (± 10 %), 50 – 60 Hz, 32 A, 7 kVA, 1 Phase plus N or 2 Phase, grounding wire	
Mass Spectrometer (MS)	230 VAC, 50 – 60 Hz, 250 VA	Flexible, worldwide power and current configurations
External Infrared Furnace	230 VAC, 50 – 60 Hz, 1,500 VA	
G4 PHOENIX	230 VAC, 50 – 60 Hz, 2,200 VA	



*) Depending on configuration

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