REPORT:

A2.1.1: Report on the gas calibrants available, existing gap and recommendation to bridge the gap ensuring that commercial laboratories can be compliant with ISO21087:2019

Authors: Karine Arrhenius, Thomas Bacquart, Abigail Morris, Niamh Moore

Confidentiality: Public

Submission date: 10.02.2021

Revision: -

https://www.sintef.no/projectweb/metrohyve-2

Report A2.1.1: Report on gas calibrants, availability, gaps and recommendations	
Funding European Metrology Program for Innovation and Research	**Grant agreement no:** 19ENG04
Project name Metrology for Hydrogen Vehicles 2	**Project short name** MetroHyVe 2
Author(s) Karine Arrhenius RISE karine.arrhenius@ri.se Thomas Bacquart NPL thomas.bacquart@npl.co.uk Abigail S. Morris NPL abigail.morris@npl.co.uk Niamh Morre NPL niamh.moore@npl.co.uk	**Pages** 23 pages

Summary

This report was written as part of activity A2.1.1 from the EMPIR Metrology for Hydrogen Vehicles 2 (MetroHyVe2) project. The three-year European project commenced on 1st August 2020 and focused on providing solutions to four measurement challenges faced by the hydrogen industry (flow metering, quality assurance, quality control, sampling and fuel cell stack testing). For more details about this project please visit website address.

Confidentiality	Public

This project "Metrology for Hydrogen Vehicles 2" (MetroHyVe 2) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union s Horizon 2020 research and innovation programme under Grant agreement No [19ENG04].

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Contents

1 - Introduction

Several European laboratories are developing the capability to measure the contaminants specified in ISO 14687:2019 [1] and EN 17124:2018 [2] as part of European projects (i.e. EMPIR project 16ENG01 MetroHyVe, Horizon 2020 project HYDRAITE) or of businesses (i.e. Air Liquide, Linde). The new standard ISO 21087:2019 [3] is setting uncertainty thresholds and validation procedures to be met (i.e. relative measurement uncertainty below 20 %, trueness validation close to ISO14687:2019 threshold). A lack of gas calibrants with sufficiently low uncertainty (i.e. formaldehyde and ammonia), reference materials for validation and inter-laboratory comparison are the most urgent identified barriers before European commercial laboratories can demonstrate their compliance to ISO 21087:2019 [3] requirements and their ability to measure contaminants in ISO 14687:2019 [1]. Reference materials are only available for the non-reactive contaminants in hydrogen; there is a lack of reference materials for NH_3, CH_2O, CH_2O_2, halogenated or sulphur compounds.

The project MetroHyVe 2 aims among others at developing gas calibrants and reference materials needed by European laboratories to validate their analytical methods according to ISO 21087:2019 [3]. The first step towards this goal is to identify the status regarding the commercial availability of gas calibrants. To do so, the industry needs (companies, analyser manufacturers and analytical laboratories) must be identified. For this purpose, a survey was produced and sent to relevant stakeholders. This report evaluates the responses received in order to identify the gas calibrants already available, the existing gaps and finally gives recommendations to bridge the gaps.

2 - Survey

A questionnaire was produced using SurveyMonkey, an online survey software. Screenshots of all the questions in the survey are shown in the Annex. The survey was sent mid-November 2020 to 23 different contacts representatives for companies, analyser manufacturers and analytical laboratories. In January 2021, 10 responses had totally been received. The relatively high number of responses received (43% of industry contacted) demonstrated that the topic is of importance for the industry.

The survey first asked about the current situation in the industry (questions 1-3), the industry needs (questions 4-6, 8-9) and about the knowledge of commercial offering (question 7). Questions 1 and 2 asked about the gas calibrants already available for the individual species and the total species (sulphur, hydrocarbons, halogenated) and the amount fractions for these gas calibrants. Question 3 asked about available multi-component gas calibrants. Questions 4, 5 and 6 asked about required gas calibrants in hydrogen, the required amount fractions and the required cylinder size (and pressure). Question 7 asked if the participant has knowledge about the commercial availability of the required gas calibrants. Question 8 asked if the participants need gas calibrants as multi-component gas standards and finally question 9 asked about which specific compounds among the “total components” are requested.

3 – Survey answers

3.1 – Available calibrants

3.1.1 – Available binary calibrants

The results of the survey are summarized in the following table for the available binary calibrants in hydrogen matrix:

Table 1 – Available binary calibrants

Species	Percentage of participants already having the calibrants in use to perform hydrogen quality analysis	Percentage of binary calibrants produced with dynamic methods for the participants having the calibrants	Lowest amount fractions available in µmol/mol	Most common amount fractions available in µmol/mol	EN17124:2018 ISO14687:2019 threshold (µmol/mol)
Water	50%	20%	2	5	5
Methane	80%	25%	1	2	100
Oxygen	80%	25%	1	5	5
Helium	70%	30%	5	300	300
Nitrogen	70%	30%	5	10 – 100 - 300	300
Argon	70%	30%	5	10 – 100 - 300	300
Carbon dioxide	80%	25%	1	2 to 5	2
Carbon monoxide	70%	60%	0.1	1	0.2
Formaldehyde	40%	100%	0.1	1 -5	0.2
Formic acid	30%	100%	1	>2 (up to 180)	0.2
Ammonia	50%	100%	0.2	1 – 10	0.1
Total hydrocarbons	60%	33%	1	2 - 10	2
Total sulphur compounds	50%	100%	0.004	1	0.004
Halogenated compounds	80%	75%	1	1	0.05

Some of the calibrants such as formaldehyde and acid formic were frequently mentioned as being in other matrices than hydrogen such nitrogen. Ammonia and water were also mentioned as being in nitrogen matrix by some participants but the majority of the participants having access to these calibrants have them in hydrogen matrix. A helium matrix is also mentioned by one participant for total hydrocarbons and another participant commented that they have halogenated components in nitrogen matrix

Binary calibrants for water, methane, oxygen, helium, nitrogen, argon, carbon dioxide, carbon monoxide, total hydrocarbons and halogenated compounds are already available for most of the participants. As expected, binary calibrants for formaldehyde and formic acid are less common (available respectively for only 40% and 30% of the participants) and always produced using dynamic methods. Binary calibrants for carbon monoxide, ammonia, halogenated compounds and total sulphur compounds are mostly produced with dynamic methods at the participants facility.

The binary calibrants are mostly available at amount fractions a bit lower or equal to the EN17124:2018 [2], ISO14687:2019 [1] thresholds with notable exceptions for the total sulphur compounds, for formic acid and for halogenated compounds for which the calibrants are most commonly available at much higher amount fractions that the thresholds.

The first outcome of this survey is that two groups of gas standards emerge based on the nature of the contaminants:

- Gravimetric gas standards: water, methane, oxygen, helium, nitrogen, argon, carbon dioxide and hydrocarbons binary standards seem largely available (>60% in use at laboratories) in gas cylinder. The reported gas standards have amount fractions coherent with ISO14687:2019 [1] threshold.

The sole outlier seems to be water gas standard with a lower level of usage. Further investigation on the reason behind the lower adoption of water gas standard may be useful.

- Dynamic gas standards: carbon monoxide, formaldehyde, formic acid, ammonia, total sulphur compounds and halogenated compounds gas standards are mainly dynamically generated (>60% and up to 100%). The use of dynamic standard presents additional challenges depending on the original sources for the dilution (use of pure compounds or gravimetric standard with high amount fraction of the compound of interest). Ensuring that the dynamic dilution system is operating correctly is important and can be done through regular maintenance and calibration of the dilution system (flow metering, critical orifices). Reactive gases dilution presents additional challenges in term of stabilization and verification if external validation (with gravimetric standards) cannot be applied.

3.1.2 – Available multi-component calibrants

Many participants indicate that they have access to multi-component calibrants containing from two-three species (for example helium, argon, nitrogen, or oxygen, methane, carbon dioxide) and up to seven species (for example methane, helium, nitrogen, argon, carbon dioxide, carbon monoxide, oxygen). For some participants, the calibrants have been purchased as a certified mixture that is then diluted with hydrogen at their facility. Methane, helium, nitrogen, argon, carbon dioxide, carbon monoxide, oxygen are the species which are most mentioned as components in available multi-component calibrants. Sulphur compounds, total halogenated compounds, formaldehyde, ammonia and formic acid have not been cited as one of the species in available multi-component calibrants. However, some multi-component calibrants named by participants are for the so-called total species; for example, a multi-component calibrant can contain hydrogen sulphide, methyl mercaptan and ethyl mercaptan.

The first outcome is that several multi-component mixtures are commercially available, mostly for inert gases. It seems that there are no standardized multi-component calibrants. Reactive species are not included in these types of standards probably due to the difficulty to keep these species stable in hydrogen matrix at low amount fraction.

There are three aspects that could increase knowledge for multi-components calibrants:

- New studies on binary gravimetric calibrants for reactive species.
- Test of new multi-component calibrant: the cost for such a study is probably high, therefore commercial gas calibrant providers may require metrological support before developing new products.
- Better understanding of the laboratory equipment. Different instruments can analyze a number of compounds at defined detection limits; therefore, specific compositions may be better suited and can be based on the available equipment at each laboratory. A further topic may be to standardize multi-component calibrants for inert gases.

The advantages of multi-component calibrants are to reduce the cost and place, and consequently reduce health and safety risks.

The project MetroHyVe2 will provide new studies on binary calibrants (ammonia and formaldehyde) and studies on multi-component calibrants to hep developing the commercial uptake of gas calibrants for the hydrogen industry.

3.2 – Required calibrants

3.2.1 – Required binary calibrants

The results of the survey are summarized in the following table for the required calibrants:

Table 2 – Available binary calibrants

Species	Percentage of participants requiring calibrant per species	Percentage of participants among those requiring the calibrant who would use the calibrant to prepare gas mixtures using dynamic methods	Lowest amount fractions required in µmol/mol *	Most common amount fractions required in µmol/mol *	Longest desired stability period (years) *	Most commonly desired stability period (years)	Most commonly desired cylinder size in liter (pressure in bar)
Water	30%	33%	5	5	3	2	10 or 50 (100)
Methane	0%	-	-	-	-	-	-
Oxygen	0%	-	-	-	-	-	-
Helium	10%	0%	50	300	5	1-2	10
Nitrogen	0%	-	-	-	-	-	-
Argon	0%	-	-	-	-	-	-
Carbon dioxide	0%	-	-	-	-	-	-
Carbon monoxide	10%	60%	0.2	0.2	3	2	10
Formaldehyde	50%	20%	0.01	0.2	2	1-2	10
Formic acid	50%	0%	0.2	0.2 – 0.5	3	1-2	10
Ammonia	20%	0%	0.1	0.1	3	1-2	10
Total hydrocarbons	30%	33%	2	2	5	1-2	10
Total sulphur compounds	40%	25%	0.004	0.004	3	1-2	10
Halogenated compounds	60%	17%	0.05	0.05	5	1-2	10

*some participants that have not indicated that they required species as calibrant have answered about the required fraction amounts, stability period and cylinder size

A majority of the participants (60%) required a calibrant for halogenated compounds. In the same way, calibrant containing formaldehyde, formic acid (both required by 50% of the participants) and total sulphur compounds (required by 40% of the participants) are among the most required calibrants. On the contrary, calibrants for methane, oxygen, nitrogen, argon (all not required by the participants), helium and carbon monoxide (both required only by 10% of the participants) are not needed by the stakeholders having answered our survey.

The desired amount fraction was usually at the EN17124:2018 [2] / ISO14687:2019 [3] thresholds and the most common desired stability period was 1-2 years with some requirements for longer stability period (3 or 5 years). Finally, a majority of participants required the calibrant to be prepared in 10-liter cylinders.

Based on the outcome of the survey, the gas metrology community and calibrants providers should focus on supporting the industry in the following areas:

- Development of stable gravimetric calibrants for formic acid, ammonia and formaldehyde at amount fraction close to ISO14687:2019 [1] thresholds and with a shelf life of minimum one year. The activity is already planned in MetroHyVe 2 project (activities 2.1 and 2.2).

- Development of solution for halogenated compounds: the challenge for these compounds will be to test various compounds requested by the industry. According to section 3.2.2, a large number of compounds are of interest. The project MetroHyVe 1 [4] has investigated the stability of a few halogenated compound. However, new discussions with the industry are needed to identify five key components. Moreover, the behaviour of halogenated compounds in gas cylinder can differ completely from compound to compound.
- Development of stable sulphur calibrants at ISO14687 [1] threshold with shelf life of one year. In MetroHyVe2 activity 2.2 several types of cylinders will be investigated for this purpose.

3.2.2 – Required multi-component calibrants

When participants were asked if they desired the previously stated amount fractions to be in a multi-component gas standard and if so, to select the components to be in the same gas calibrant cylinder, many different combinations were mentioned. However, some of the combinations were requested by several participants. A multi-component often asked contains most of the "stable" species in one cylinder: nitrogen, argon, carbon monoxide, methane, oxygen, helium. Calibrants for halogenated compounds or sulphur compounds were mentioned several times. Finally, different combinations of reactive species were mentioned (many of these combinations included formaldehyde). Examples of combination requested are:

- Water, formaldehyde, ammonia
- Carbon monoxide, formaldehyde, hydrogen sulphide
- Carbon monoxide, formaldehyde, formic acid
- Formaldehyde, formic acid
- Oxygen, formaldehyde, ammonia
- Ammonia, water

One participant commented that multi-component calibrants are not necessary but can be used to evaluate the impact of multi-component analysis.

The difficult with multi-component calibrants is to find the correct match between composition, gas cylinder and amount fractions. There is a risk of cross reactivity and prior to developing new calibrants including reactive species, it is critical to determine their stability in specific cylinders and then if there is cross reactivity. It is important to first develop an understanding of binary components in gas cylinders.

MetroHyVe2 will contribute by studying some new multi-component calibrants, however more studies are necessary to develop all the multi-component calibrants required above.

3.2.3 – Specific compounds for "total" species

In the last question of the survey, participants were asked which specific compounds are desired as calibrants. In Table 4, the compounds that were mentioned by the participants are regrouped per family. There was no clear consensus, but some components were mentioned several times (marked in bold in the table).

Table 4 – Components from the "total" species required by participants in calibrants

	Mentioned components
Total Hydrocarbons	**C_2H_6**, **C3** to C10 linear alkanes, $CH_3)_2CO$, MTBE*
Total Sulphurs	**H_2S**, **CS_2**, **COS**, SO_2, **CH_4S**, C_2H_6S**, C_4H_4S
Total halogenated	**HCl**, Cl_2, CH_3Cl, **$CHCl_3$**, CH_2CCl_2, CCl_4, NaCl, Br_2, CH_3Br, **CH_2Cl_2,** C_2Cl_4

*TBME: tert-butyl methyl ether

** C2H6S is here both ethyl mercaptan and dimethylsulphide which have both been mentioned

Many different components are requested by the participants. A majority of these components has probably never been tested in hydrogen matrix. There are two possibilities:

- The analytical laboratories performing the hydrogen fuel quality agree on a set of relevant compounds for total species and consequently shorten the list to allow the gas calibrant providers to offer the requested calibrant in a near future.

- The analytical laboratories need all the components mentioned in Table 4. There is then a need for gas calibrant providers and gas metrology community to study the stability of each component first as binary standard and then as multi-component standards. It will probably require funding and time to achieve this ambitious target,

3.3 – Participants knowledge on the existence of calibrants

In order to establish the gaps in existing calibrants, participants were also asked if they know if calibrants were available for every of the gaseous species in EN17124:2018 / ISO14687:2019. The responses are presented in Table 5.

Table 5 – Participants knowledge on the existence of calibrants

Species	Percentage of participants who answered “I know the calibrant is available”	Percentage of participants who answered “I know the calibrant is not available”	Percentage of participants who answered “I don´t know”
Water	40%	50%	10%
Methane	60%	25%	15%
Oxygen	60%	25%	15%
Helium	60%	25%	15%
Nitrogen	60%	25%	15%
Argon	60%	25%	15%
Carbon dioxide	60%	25%	15%
Carbon monoxide	50%	50%	0%
Formaldehyde	30%	55%	15%
Formic acid	15%	70%	15%
Ammonia	25%	60%	10%
Total hydrocarbons	50%	35%	15%
Total sulphur compounds	25%	50%	25%
Halogenated compounds	15%	70%	15%

Only a few participants answered that they do not have knowledge about the existence of the calibrants in hydrogen matrix (less than 25% answered “I don´t know”).

A majority of participants (at least 50%) believes that calibrants for halogenated compounds, formic acid, ammonia, formaldehyde, total sulphur compounds, carbon monoxide and water are not yet available. Some participants comment that this is due to the low concentrations required, problem with stability or high costs. It is worth noticing that even if a majority of participants affirm knowing that ammonia and water cannot be found as calibrant in hydrogen matrix, only 20 or 30% of the participants indicated that they require these calibrants. Otherwise, there is a correlation between the required calibrants (Table 2) and the calibrants considered as missing by the participants.

Globally, there is a lack of awareness of the analytical laboratories regarding the gas calibrants availability. A discussion platform between gas calibrants providers and analytical laboratories providing hydrogen fuel quality assessment may be relevant to develop in order to share information, discuss research and development requirements and develop a better understanding between both parts.

4 – Existing gaps

This section aims to conduct a gap analysis of the calibrant needs for hydrogen quality assessment.

4.1 – Existing gaps in binary calibrants

When summarizing the information from Tables 1, 2 and 3, it can be concluded that binary calibrants for methane, oxygen, helium, nitrogen, argon, carbon dioxide are already available and not required by the participants of the survey.

As it can be seen in Table 1, binary calibrants for formaldehyde and formic acid are less common (available respectively for only 40% and 30% of the participants) and always produced using dynamic methods (and not always in hydrogen). The survey didn´t ask either for the expanded uncertainties for the calibrants in use nor for the traceability to primary standards. Moreover, a majority of the participants indicating knowing that there are no calibrant in hydrogen matrix currently available for these two compounds (Table 3) which probably indicates that calibrants for these two compounds are produced in-house for example from the pure substances. A majority of the participants required calibrants for these two components.

The production of calibrants for the total species seem to be of interest for the participants of the survey; mostly for halogenated compounds and sulphur compounds but to a lower extend for hydrocarbons. Needs for these calibrants are detailed in the next section, as they are per say multi-components calibrants.

Finally, even interest for the production of calibrants for water and carbon monoxide has been shown by the participants of the survey, with mention of stability issues for water.

Based the outcome of the survey, the gas metrology community and calibrants providers should focus on supporting the industry in the following areas:

- Development of stable gravimetric calibrants for formic acid, ammonia and formaldehyde close to ISO 14687:2019 threshold and with a shelf life of minimum one year. An activity is already planned in MetroHyVe 2 project activity 2.1 and 2.2.
- Development of a solution for halogenated compounds: discussion on the critical components for analytical laboratories. Study of stability of these components in hydrogen matrix.
- Development of stable sulphur calibrants at ISO 14687 threshold with shelf life of one year. MetroHyVe 2 (activity 2.2) will investigate several cylinder types for this purpose.
- Development of stable gas standard for water at ISO 14687:2019 threshold.

4.2 – Existing gaps in multi-component calibrants

According to the participants, calibrants for the total species are lacking mostly for halogenated compounds and these should preferably include hydrogen chloride (HCl), chloroform($CHCl_3$), dichloromethane (CH_2Cl_2) but even perchloroethylene (C_2Cl_4), dichlorine (Cl_2), chloromethane (CH_3Cl), dichloroethane (CH_2CCl_2), carbon tetrachloride (CCl_4), sodium chloride (NaCl), bromine Br_2 and bromomethane (CH3Br) have been mentioned. Even calibrants for total sulphur compounds need to be produced and should preferably include hydrogen sulphide (H_2S), carbon disulphide (CS_2), carbonyl sulphide (COS) and methyl mercaptan (CH_4S) but even sulphur dioxide (SO_2), ethyl mercaptan (C_2H_6S), dimethyl sulphide (C_2H_6S), thiophene (C_4H_4S) have been mentioned.

Total hydrocarbons calibrants if produced should preferably include ethane (C_2H_6) and propane (C_3H_8) but even longer linear alkanes (up to C10). Acetone ($(CH_3)_2CO$) and tert butyl methyl ether (MTBE) have also been mentioned.

Even if binary calibrants for methane, oxygen, helium, nitrogen, argon, carbon dioxide are not required, a multi-component calibrant with all these components and carbon monoxide in the same mixture is required by several participants.

Finally, different combinations of multi-components including formaldehyde, water, formic acid, ammonia, oxygen, carbon monoxide and hydrogen sulphide are also required by the participants.

Aanalytical laboratories performing hydrogen fuel quality need to agree on a set of relevant compounds for total species, otherwise, if all the components mentioned in the survey are to be part of gas calibrants, more studies (implying more funding and more time) are needed.

5 – Recommendations

This report outlines a number of calibrants that are of interest for the industry as for example a multi-component calibrant containing methane, oxygen, helium, nitrogen, argon, carbon dioxide and carbon monoxide at amount fractions corresponding to their respective EN17124:2018 / ISO14687:2019 thresholds and preferably in 10 liter cylinders. Binary calibrants for reactive species and specifically for formaldehyde and formic acid are also highly required. Among the total species, development of calibrants for halogenated components should be prioritized.

The calibrants should be stable for a period of at least one year and preferably two years.

The project MetroHyVe 2 will support the recommendations of this survey report through studying new binary calibrants for ammonia and formaldehyde and new multicomponent mixtures as the ones given in Table 6.

.

Table 6 – Examples of multicomponent calibrants planned to be tested in MetroHyVe 2

Species	Multicomponent 1	Multicomponent 2	Multicomponent 3
Water	5	-	5
Methane	-	-	100
Oxygen	5	5	5
Helium	-	-	300
Nitrogen	300	-	300
Argon	-	-	300
Carbon dioxide	2	-	2
Carbon monoxide	-	-	0.2
Formaldehyde	-	0.05 - 0.3	0.05 - 0.3
Formic acid	-	0.05 - 0.3	0.05 - 0.3
Ammonia	-	0.05 - 0.3	0.05 - 0.3
Total hydrocarbons	2 - Propane	2 - n-butane, ethanol or methanol, benzene selected as compounds of interest to test	2 – Ethane
Total sulphur compounds	0.0003 – 0.007 – H_2S	0.0003 – 0.007 – DMS/CS_2	0.0003 – 0.007 - COS
Halogenated compounds	0.05 – $C_4Cl_4F_6$	0.05 – CCl_4	0.05 –CH_2Cl_2

This report highlights the need to undertake several actions in order to support the hydrogen fuel quality and analytical laboratory:

Technical studies:

- Development of binary gas calibrant for ammonia, formic acid, formaldehyde
- Development of a solution for gas calibrants covering total sulphur compounds and halogenated compounds.
- Development of new water amount fraction gas calibrant with longer lifetime

Coordination activities:

- Standardize the components required for calibration of total components. This activity may be relevant to metrology communities or standardisation committees.
- Gas calibrants usage, it is important for gas calibrant providers to understand if the calibrant is meant for calibration or quality control in order to define the correct ranges and uncertainty. The survey in this report only assesses the availability of calibrants. Further discussions should be organised and gas calibrants should be linked to specific one use: calibration or quality control.

Communication activities:

- Develop a platform of discussion between analytical laboratories for hydrogen fuel quality and gas providers in order to share issues, requirements and availability of calibrants.

References

[1] ISO14687:2019 Hydrogen fuel quality – product specification., Geneva, Switzerland, ISO, International Organization for Standardization, 2019

[2] EN17124:19 Hydrogen fuel—product specification and quality assurance—proton exchange membrane (PEM) fuel cell applications

[3] ISO21087:2019 Gas analysis – Analytical methods for hydrogen fuel – proton exchange membrane (PEM) fuel cell applications for road vehicles, Geneva, Switzerland, ISO, International Organization for Standardization, 2019

[4] Metrology for hydrogen vehicles EURAMET EMPIR 16ENG01, 2017-2020, www.euramet.org/research-innovation

Annex – Survey

MetroHyVe 2 survey - Assessment of industry needs for hydrogen gas calibrants

Survey on gas standards/reference material for hydrogen fuel quality analytical laboratory

This questionnaire is prepared as part of activity A2.1.1 from the EMPIR Metrology for Hydrogen Vehicles 2 (MetroHyVe2) project. The three year European project commenced on 1st August 2020 and focuses on providing solutions to four measurement challenges faced by the hydrogen industry (flow metering, hydrogen quality control, sampling and fuel cell stack testing).

The objective is to understand the current gap in gas calibrant and gas standards that are currently an issue for your laboratory or business in order to supply hydrogen fuel quality measurements to the whole hydrogen economy and industry.

You should be aware that the current hydrogen quality specification in Europe is EN 17124:2018, however there is an international standard ISO 14687:2019 and SAE J2719:2020.

A requirement for analytical laboratory is included in ISO 14687:2019 that results of analysis should comply with ISO 21087:2019.

Please find below threshold amount fractions as listed in EN 17124:2018 for your reference.

Components	EN 17124:2018 ISO 14687:2019 threshold level (µmol/mol)
Water	5
Methane	100
Oxygen	5
Helium	300
Nitrogen	300
Argon	300
Carbon dioxide	2
Carbon monoxide	0.2
Formaldehyde	0.2
Formic acid	0.2
Ammonia	0.1
Total hydrocarbons (TC)	2 (excluding methane)
Total sulphur compounds	0.004
Halogenated compounds	0.05

OK

0 of 10 answered

1. Tick the binary gas calibrants already available and in use in your laboratory (please tick box for 'Yes' and leave empty for 'No')
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	Is this calibrant already in use to perform hydrogen quality analysis (compliance with ISO 21087)?	Is this standard used to prepare calibration gas mixtures using dynamic methods?
Water	☐	☐
Methane	☐	☐
Oxygen	☐	☐
Helium	☐	☐
Nitrogen	☐	☐
Argon	☐	☐
Carbon dioxide	☐	☐
Carbon monoxide	☐	☐
Formaldehyde	☐	☐
Formic acid	☐	☐
Ammonia	☐	☐
Total Hydrocarbons (TC) excluding methane	☐	☐
Total sulphur compounds	☐	☐
Halogenated compounds	☐	☐

Any comments or other matrix gas used?

2. Please enter amount fractions (µmol/mol) of gas calibrant components already in use in your laboratory for hydrogen quality activities (where applicable).
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please add information on the matrix gas.

Water

Methane

Oxygen

0 of 10 answered

2. Please enter amount fractions (µmol/mol) of gas calibrant components already in use in your laboratory for hydrogen quality activities (where applicable).
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please add information on the matrix gas.

Water	
Methane	
Oxygen	
Helium	
Nitrogen	
Argon	
Carbon dioxide	
Carbon monoxide	
Formaldehyde	
Formic acid	
Ammonia	
Total Hydrocarbons (TC) excluding methane	
Total sulphur compounds	
Halogenated compounds	

3. Are you currently using multi-component gas calibrants in your laboratory for hydrogen quality activities? If so, please select which components are present in the same calibrant cylinder.
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	Water	Oxygen	Methane	Helium	Nitrogen	Argon	Carbon dioxide	Carbon monoxide	Formaldehyde	Formic acid	Ammonia	Total hydrocarbons (TC) excluding methane	Total sulphur compounds
Standard 1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

0 of 10 answered

3. Are you currently using multi-component gas calibrants in your laboratory for hydrogen quality activities? If so, please select which components are present in the same calibrant cylinder.
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	Water	Oxygen	Methane	Helium	Nitrogen	Argon	Carbon dioxide	Carbon monoxide	Formaldehyde	Formic acid	Ammonia	Total hydrocarbons (TC) excluding methane	Total sulphur compounds
Standard 1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 7	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Any comments?

4. Are there additional gas calibrant you require that you do not already have available? (please tick box for 'Yes' and leave empty for 'No')
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	Is this gas calibrant needed to perform hydrogen quality analysis (compliance with ISO 21087)?	Would the standard be used to prepare calibration gas mixtures using dynamic method?
Water	☐	☐
Methane	☐	☐
Oxygen	☐	☐

0 of 10 answered

4. Are there additional gas calibrant you require that you do not already have available? (please tick box for 'Yes' and leave empty for 'No')
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	Is this gas calibrant needed to perform hydrogen quality analysis (compliance with ISO 21087)?	Would the standard be used to prepare calibration gas mixtures using dynamic method?
Water	☐	☐
Methane	☐	☐
Oxygen	☐	☐
Helium	☐	☐
Nitrogen	☐	☐
Argon	☐	☐
Carbon dioxide	☐	☐
Carbon monoxide	☐	☐
Formaldehyde	☐	☐
Formic acid	☐	☐
Ammonia	☐	☐
Total Hydrocarbons (TC) excluding methane	☐	☐
Total sulphur compounds	☐	☐
Halogenated compounds	☐	☐

any comments

5. Please enter the desired amount fraction (µmol/mol) and the desired stability period for each required gas calibrant component where applicable (e.g. water: 5 µmol/mol, 2 years)

Water

Methane

Oxygen

Helium

0 of 10 answered

5. Please enter the desired amount fraction (µmol/mol) and the desired stability period for each required gas calibrant component where applicable (e.g. water: 5 µmol/mol, 2 years)

Water	
Methane	
Oxygen	
Helium	
Nitrogen	
Argon	
Carbon dioxide	
Carbon monoxide	
Formaldehyde	
Formic acid	
Ammonia	
Total Hydrocarbons (TC) excluding methane	
Total sulphur compounds	
Halogenated compounds	

6. Please select cylinder size for the desired gas calibrant (one compound in hydrogen matrix)?

	5L cylinder (100 bar)	10L cylinder (100 bar)	50L cylinder (100 bar)
Water	○	○	○
Methane	○	○	○
Oxygen	○	○	○
Helium	○	○	○
Nitrogen	○	○	○
Argon	○	○	○
Carbon dioxide	○	○	○
Carbon monoxide	○	○	○

6. Please select cylinder size for the desired gas calibrant (one compound in hydrogen matrix)?

	5L cylinder (100 bar)	10L cylinder (100 bar)	50L cylinder (100 bar)
Water			
Methane			
Oxygen			
Helium			
Nitrogen			
Argon			
Carbon dioxide			
Carbon monoxide			
Formaldehyde			
Formic acid			
Ammonia			
Total Hydrocarbons (TC) excluding methane			
Total sulphur compounds			
Halogenated compounds			

7. Do you know if your desired gas calibrant is already commercially available?
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	I know it is available	I know it is not available	I don't know
Water			
Methane			
Oxygen			
Helium			
Nitrogen			
Argon			
Carbon dioxide			

0 of 10 answered

7. Do you know if your desired gas calibrant is already commercially available?
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	I know it is available	I know it is not available	I don't know
Water	○	○	○
Methane	○	○	○
Oxygen	○	○	○
Helium	○	○	○
Nitrogen	○	○	○
Argon	○	○	○
Carbon dioxide	○	○	○
Carbon monoxide	○	○	○
Formaldehyde	○	○	○
Formic acid	○	○	○
Ammonia	○	○	○
Total Hydrocarbons (TC) excluding methane	○	○	○
Total sulphur compounds	○	○	○
Halogenated compounds	○	○	○

any comments?

8. Would you desire the previously stated amount fractions (question 5) to be in a multi-component gas standard? If so, please select the components you would require to be in the same gas calibrant cylinder?
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	Water	Methane	Oxygen	Helium	Nitrogen	Argon	Carbon dioxide	Carbon monoxide	Formaldehyde	Formic acid	Ammonia	Total hydrocarbons (TC)	Total sulphur compounds
Standard 1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

0 of 10 answered

8. Would you desire the previously stated amount fractions (question 5) to be in a multi-component gas standard? If so, please select the components you would require to be in the same gas calibrant cylinder?
The question refers to gas calibrants in hydrogen matrix. If not in hydrogen matrix, please provide additional information in comment section.

	Water	Methane	Oxygen	Helium	Nitrogen	Argon	Carbon dioxide	Carbon monoxide	Formaldehyde	Formic acid	Ammonia	Total hydrocarbons (TC)	Total sulphur compounds
Standard 1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standard 6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

any comments?

9. Would you have specific compounds desired for the 'total' components stated in the EN 17124 (Total hydrocarbons, Total sulfurs and total halogenates)? If so, please name them in the sections below.

Total hydrocarbons

Total sulfurs

Total halogenates

* 10. Please provide your contact information

Name

Company

0 of 10 answered

9. Would you have specific compounds desired for the 'total' components stated in the EN 17124 (Total hydrocarbons, Total sulfurs and total halogenates)? If so, please name them in the sections below.

Total hydrocarbons

Total sulfurs

Total halogenates

* 10. Please provide your contact information

Name	
Company	
Country	
Email Address	
Phone Number	

DONE