

Key comparisons CCQM-K1.c, EUROMET.QM-K1.c and APMP.QM-K1.c

Key comparison CCQM-K1.c

MEASURAND : Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N₂)
 NOMINAL VALUE : 100 µmol/mol

x_i : result of measurement carried out by laboratory i

u_i : combined standard uncertainty of x_i

$x_{i\text{grav}}$: gravimetric value of the NO amount-of-substance fraction in the cylinder received by laboratory i

$u_{i\text{grav}}$: combined standard uncertainty of $x_{i\text{grav}}$

Lab i	x_i / (µmol/mol)	u_i / (µmol/mol)	$x_{i\text{grav}}$ / (µmol/mol)	$u_{i\text{grav}}$ / (µmol/mol)	Date of measurement
NPL	100.00	0.20	100.070	0.007	96-02
NIST	100.20	0.27	100.090	0.007	95-06
NMi-VSL*	100.10	0.20	100.100	0.007	95-04
BNM-LNE*	100.08	0.04	100.110	0.007	96-01
KRISS	100.90	0.35	100.130	0.007	95-03
NRLM*	100.39	0.25	100.150	0.007	95-03
NRCCRM*	105.80	0.53	100.160	0.007	95-04
VNIIM	101.80	0.50	100.170	0.007	95-04
OMH*	100.70	0.50	100.180	0.007	95-06

*At the time of the comparison, NMIJ (Japan) was designated as NRLM; VSL (Netherlands) as NMi-VSL; LNE (France) as BNM-LNE; NIM (China) as NRCCRM; and MKEH (Hungary) as OMH.

Key comparison EUROMET.QM-K1.c

MEASURAND : Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N₂)
NOMINAL VALUE : 100 µmol/mol

$x_{i\text{-EUR}}$: result of measurement carried out by laboratory i

$u_{i\text{-EUR}}$: combined standard uncertainty of $x_{i\text{-EUR}}$

$x_{i\text{grav-EUR}}$: gravimetric value of the NO amount-of-substance fraction in the cylinder received by laboratory i

$u_{i\text{grav-EUR}}$: combined standard uncertainty of $x_{i\text{grav-EUR}}$

Lab i	$x_{i\text{-EUR}}$ / (µmol/mol)	$u_{i\text{-EUR}}$ / (µmol/mol)	$x_{i\text{grav-EUR}}$ / (µmol/mol)	$u_{i\text{grav-EUR}}$ / (µmol/mol)	Date of measurement
BNM-LNE*	95.08	0.33	95.070	0.062	02-08
NPL	95.2	0.15	95.094	0.062	02-07
VNIIM	96.6	0.45	95.055	0.062	02-11
NMi-VSL*	94.8	0.15	94.732	0.062	02-09
GUM	95.8	0.75	95.172	0.062	03-01
CEM	95.8	0.45	95.228	0.062	02-09
METAS	95.12	0.21	94.843	0.062	02-09
CHMI	94.87	0.80	95.064	0.062	02-09
FMI	94.8	0.75	95.158	0.062	02-09
IPQ	95.22	0.20	95.120	0.062	02-07

*At the time of the comparison, VSL (Netherlands) was designated as NMi-VSL and LNE (France) as BNM-LNE.

Key comparison APMP.QM-K1.c

MEASURAND : Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N₂)
NOMINAL VALUE : 100 µmol/mol

x_{i-APMP} : result of measurement carried out by laboratory i

u_{i-APMP} : combined standard uncertainty of x_{i-APMP}

Lab i	x_{i-APMP} / (µmol/mol)	u_{i-APMP} / (µmol/mol)	Date of measurement
NIM	99.07	0.50	Jun 2006
KRISS	97.88	0.11	Aug 2006

Gravimetric value of the transfer cylinder prepared by KRISS: 97.94 µmol/mol
with a standard uncertainty of 0.1 µmol/mol.

Key comparisons CCQM-K1.c, EUROMET.QM-K1.c and APMP.QM-K1.c

MEASURAND : Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N₂)
NOMINAL VALUE: 100 µmol/mol

Key comparison CCQM-K1.c

Key comparison reference value: there is no single reference value for this comparison, the value $x_{i\text{grav}}$ is taken as the reference value for laboratory i .

The degree of equivalence of each laboratory with respect to the reference value is given by a pair of terms:

$D_i = (x_i - x_{i\text{grav}})$ and U_i , its expanded uncertainty ($k = 2$), both expressed in µmol/mol

$$U_i = 2(u_i^2 + u_{i\text{grav}}^2)^{1/2}$$

The degree of equivalence between two laboratories is given by a pair of terms:

$D_{ij} = D_i - D_j = (x_i - x_{i\text{grav}}) - (x_j - x_{j\text{grav}})$ and U_{ij} , its expanded uncertainty ($k = 2$), both expressed in µmol/mol

$$U_{ij} = 2(u_i^2 + u_j^2 + u_{i\text{grav}}^2 + u_{j\text{grav}}^2)^{1/2}$$

Key comparison EUROMET.QM-K1.c

The gravimetric value $x_{i\text{grav-EUR}}$ is taken as the reference value for laboratory i participant in EUROMET.QM-K1.c.

The degree of equivalence of laboratory i participant in EUROMET.QM-K1.c with respect to the reference value is given by a pair of terms:

$D_{i\text{-EUR}} = (x_{i\text{-EUR}} - x_{i\text{grav-EUR}})$ and $U_{i\text{-EUR}}$, its expanded uncertainty ($k = 2$), both expressed in µmol/mol

$$U_{i\text{-EUR}} = 2(u_{i\text{-EUR}}^2 + u_{i\text{grav-EUR}}^2)^{1/2}$$

Linking EUROMET.QM-K1.c to CCQM-K1.c

NMi-VSL acted as the pilot laboratory in both key comparisons, EUROMET.QM-K1.c and CCQM-K1.c. The results of the laboratories having participated in both comparisons (NMi-VSL, NPL, BNM-LNE, and VNIIM) are given in the following table, except those of VNIIM that deviated significantly from the key comparison reference value.

	CCQM-K1.c		EUROMET.QM-K1.c	
	D_i / ($\mu\text{mol/mol}$)	U_i / ($\mu\text{mol/mol}$)	$D_{i\text{-EUR}}$ / ($\mu\text{mol/mol}$)	$U_{i\text{-EUR}}$ / ($\mu\text{mol/mol}$)
NMi-VSL	0.00	0.40	0.07	0.32
NPL	-0.07	0.40	0.11	0.32
BNM-LNE	-0.03	0.08	0.01	0.66

Since the results of the three laboratories agree with the reference values within the claimed uncertainties in both comparisons, they provide some validation that the gravimetric values act as valid reference values.

It follows that:

The degrees of equivalence relative to the reference value obtained in EUROMET.QM-K1.c are transferred to CCQM-K1.c without correction:

$$D_i = D_{i\text{-EUR}} \text{ and } U_i = U_{i\text{-EUR}}$$

The degree of equivalence between two laboratories i and j participating in CCQM-K1.c or in EUROMET.QM-K1.c is given by a pair of terms:

$$D_{ij} = D_i - D_j \text{ and } U_{ij}, \text{ its expanded uncertainty } (k = 2), \text{ both expressed in } \mu\text{mol/mol}$$

$$U_{ij} = 2(u_i^2 + u_j^2 + u_{i\text{grav}}^2 + u_{j\text{grav}}^2)^{1/2} \text{ with index " -EUR " when necessary.}$$

These statements make it possible to extend the CCQM-K1.c matrix of equivalence to all participants in EUROMET.QM-K1.c

Linking APMP.QM-K1.c to CCQM-K1.c

In order to link the APMP.QM-K1.c results to those of CCQM-K1.c, a small uncertainty term is added to the uncertainty of the gravimetric value delivered by KRISS for the transfer standard.

The gravimetric value used to calculate the degrees of equivalence is equal to 97.94 $\mu\text{mol/mol}$ with standard uncertainty 0.40 $\mu\text{mol/mol}$. No pair-wise degrees of equivalence are computed from the APMP.QM-K1.c results.

Full set of degrees of equivalence (with laboratory acronyms as on January 2010)

Lab <i>i</i>	D_i	U_i	
	/ ($\mu\text{mol/mol}$)		
NPL	-0.07	0.40	CCQM-K1.c
NIST	0.11	0.53	
VSL	0.00	0.40	
LNE	-0.03	0.08	
KRISS	0.77	0.70	
NMIJ	0.24	0.50	
NIM	5.64	1.06	
VNIIM	1.63	1.00	
MKEH	0.52	1.01	
LNE	0.01	0.66	EUROMET.QM-K1.c linked to CCQM-K1.c
NPL	0.11	0.32	
VNIIM	1.55	0.91	
VSL	0.07	0.32	
GUM	0.63	1.51	
CEM	0.57	0.91	
METAS	0.28	0.44	
CHMI	-0.19	1.61	
FMI	-0.36	1.51	
IPQ	0.10	0.41	
NIM	1.13	1.28	APMP.QM-K1.c linked to CCQM-K1.c
KRISS	-0.06	0.83	

Key comparisons CCQM-K1.c and EUROMET.QM-K1.c

Complete Matrix of Equivalence for CCQM-K1.c and EUROMET.QM-K1.c (1/2)

In this table, the acronyms of laboratories are kept as they were at the time of the comparisons CCQM-K1.c and EUROMET.QM-K1.c

Lab *j* \Rightarrow

Lab *i* \Downarrow

	D_i U_i / (μmol/mol)		NPL		NIST		NMI-VSL		BNM-LNE		KRISS		NRLM		NRCCRM		VNIIM		OMH	
	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
NPL	-0.07	0.40			-0.18	0.66	-0.07	0.57	-0.04	0.41	-0.84	0.80	-0.31	0.64	-5.71	1.13	-1.70	1.07	-0.59	1.08
NIST	0.11	0.53	0.18	0.66			0.11	0.67	0.14	0.54	-0.66	0.88	-0.13	0.73	-5.53	1.18	-1.52	1.13	-0.41	1.14
NMI-VSL	0.00	0.40	0.07	0.57	-0.11	0.67			0.03	0.41	-0.77	0.80	-0.24	0.64	-5.64	1.13	-1.63	1.07	-0.52	1.08
BNM-LNE	-0.03	0.08	0.04	0.41	-0.14	0.54	-0.03	0.41			-0.80	0.70	-0.27	0.51	-5.67	1.06	-1.66	1.00	-0.55	1.01
KRISS	0.77	0.70	0.84	0.80	0.66	0.88	0.77	0.80	0.80	0.70			0.53	0.86	-4.87	1.27	-0.86	1.22	0.25	1.22
NRLM	0.24	0.50	0.31	0.64	0.13	0.73	0.24	0.64	0.27	0.51	-0.53	0.86			-5.40	1.17	-1.39	1.12	-0.28	1.13
NRCCRM	5.64	1.06	5.71	1.13	5.53	1.18	5.64	1.13	5.67	1.06	4.87	1.27	5.40	1.17			4.01	1.45	5.12	1.46
VNIIM	1.63	1.00	1.70	1.07	1.52	1.13	1.63	1.07	1.66	1.00	0.86	1.22	1.39	1.12	-4.01	1.45			1.11	1.42
OMH	0.52	1.01	0.59	1.08	0.41	1.14	0.52	1.08	0.55	1.01	-0.25	1.22	0.28	1.13	-5.12	1.46	-1.11	1.42		
BNM-LNE	0.01	0.66	0.08	0.76	-0.10	0.84	0.01	0.76			-0.76	0.95	-0.23	0.82	-5.63	1.24	-1.62	1.19	-0.51	1.20
NPL	0.11	0.32			0.00	0.61	0.11	0.50	0.14	0.31	-0.66	0.76	-0.13	0.58	-5.53	1.10	-1.52	1.04	-0.41	1.05
VNIIM	1.55	0.91	1.61	0.98	1.43	1.04	1.54	0.99	1.57	0.90	0.77	1.14	1.30	1.03	-4.10	1.39			1.02	1.35
NMI-VSL	0.07	0.32	0.14	0.50	-0.04	0.61			0.10	0.31	-0.70	0.76	-0.17	0.58	-5.57	1.10	-1.56	1.04	-0.45	1.05
GUM	0.63	1.51	0.70	1.55	0.52	1.59	0.63	1.55	0.66	1.50	-0.14	1.65	0.39	1.58	-5.01	1.84	-1.00	1.80	0.11	1.81
CEM	0.57	0.91	0.64	0.98	0.46	1.04	0.57	0.99	0.60	0.90	-0.20	1.14	0.33	1.03	-5.07	1.39	-1.06	1.34	0.05	1.35
METAS	0.28	0.44	0.35	0.58	0.17	0.68	0.28	0.58	0.31	0.43	-0.49	0.81	0.04	0.65	-5.36	1.14	-1.35	1.08	-0.24	1.09
CHMI	-0.19	1.61	-0.12	1.65	-0.30	1.69	-0.19	1.65	-0.16	1.60	-0.96	1.74	-0.43	1.68	-5.83	1.92	-1.82	1.89	-0.71	1.89
FMI	-0.36	1.51	-0.29	1.55	-0.47	1.59	-0.36	1.55	-0.33	1.50	-1.13	1.65	-0.60	1.58	-6.00	1.84	-1.99	1.80	-0.88	1.81
IPQ	0.10	0.41	0.17	0.56	-0.01	0.66	0.10	0.56	0.13	0.40	-0.67	0.80	-0.14	0.64	-5.54	1.13	-1.53	1.07	-0.42	1.08

Complete Matrix of Equivalence for CCQM-K1.c and EUROMET.QM-K1.c (2/2)

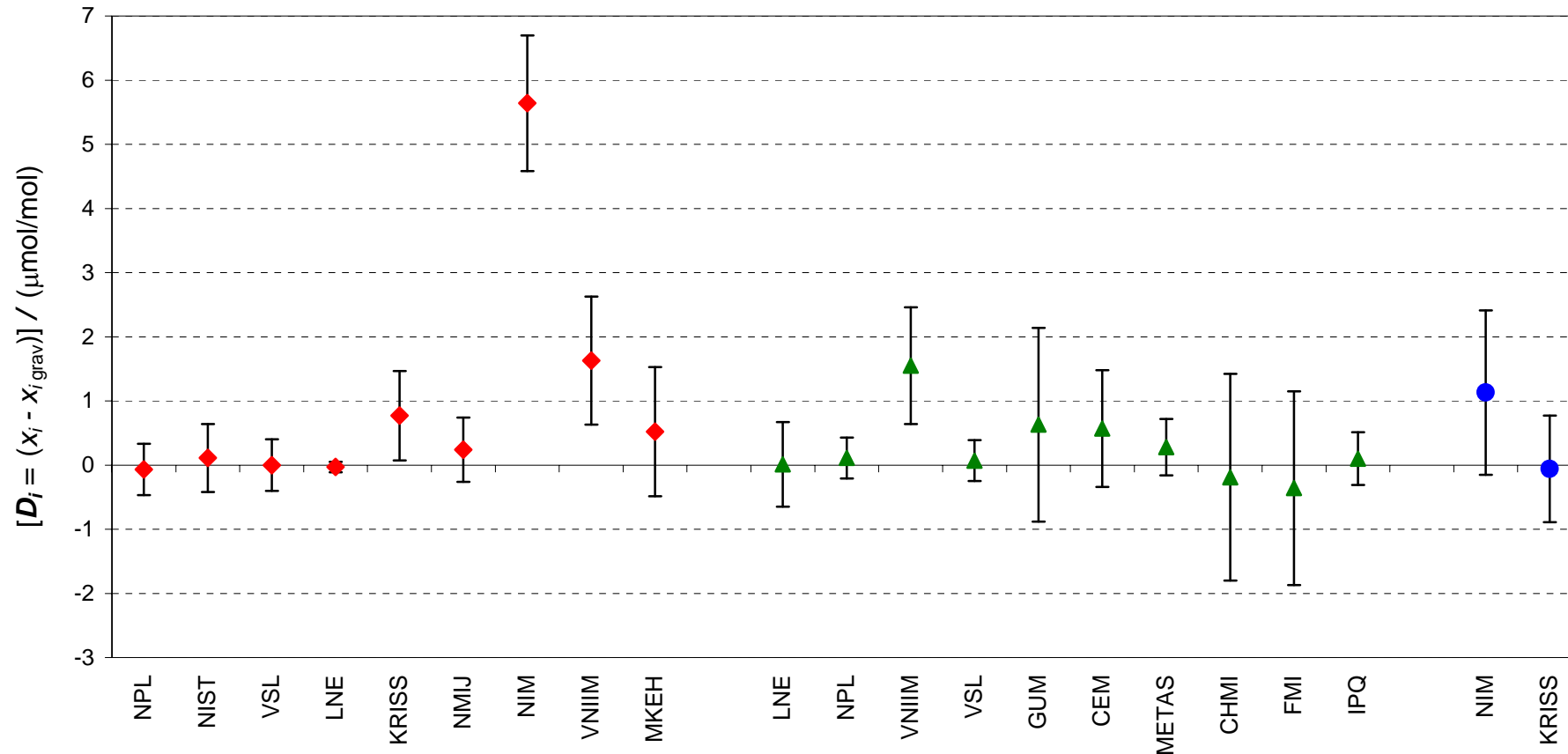
In this table, the acronyms of laboratories are kept as they were at the time of the comparisons CCQM-K1.c and EUROMET.QM-K1.c

Lab *j* →

Lab *i* ↓

	D_i U_i / (μmol/mol)		BNM-LNE		NPL		VNIIM		NMI-VSL		GUM		CEM		METAS		CHMI		FMI		IPQ	
	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
NPL	-0.07	0.40	-0.08	0.76			-1.61	0.98	-0.14	0.50	-0.70	1.55	-0.64	0.98	-0.35	0.58	0.12	1.65	0.29	1.55	-0.17	0.56
NIST	0.11	0.53	0.10	0.84	0.00	0.61	-1.43	1.04	0.04	0.61	-0.52	1.59	-0.46	1.04	-0.17	0.68	0.30	1.69	0.47	1.59	0.01	0.66
NMI-VSL	0.00	0.40	-0.01	0.76	-0.11	0.50	-1.54	0.99			-0.63	1.55	-0.57	0.99	-0.28	0.58	0.19	1.65	0.36	1.55	-0.10	0.56
BNM-LNE	-0.03	0.08			-0.14	0.31	-1.57	0.90	-0.10	0.31	-0.66	1.50	-0.60	0.90	-0.31	0.43	0.16	1.60	0.33	1.50	-0.13	0.40
KRISS	0.77	0.70	0.76	0.95	0.66	0.76	-0.77	1.14	0.70	0.76	0.14	1.65	0.20	1.14	0.49	0.81	0.96	1.74	1.13	1.65	0.67	0.80
NRLM	0.24	0.50	0.23	0.82	0.13	0.58	-1.30	1.03	0.17	0.58	-0.39	1.58	-0.33	1.03	-0.04	0.65	0.43	1.68	0.60	1.58	0.14	0.64
NRCCRM	5.64	1.06	5.63	1.24	5.53	1.10	4.10	1.39	5.57	1.10	5.01	1.84	5.07	1.39	5.36	1.14	5.83	1.92	6.00	1.84	5.54	1.13
VNIIM	1.63	1.00	1.62	1.19	1.52	1.04			1.56	1.04	1.00	1.80	1.06	1.34	1.35	1.08	1.82	1.89	1.99	1.80	1.53	1.07
OMH	0.52	1.01	0.51	1.20	0.41	1.05	-1.02	1.35	0.45	1.05	-0.11	1.81	-0.05	1.35	0.24	1.09	0.71	1.89	0.88	1.81	0.42	1.08
BNM-LNE	0.01	0.66			-0.10	0.72	-1.53	1.11	-0.06	0.72	-0.62	1.63	-0.56	1.11	-0.27	0.77	0.20	1.73	0.37	1.63	-0.09	0.76
NPL	0.11	0.32	0.10	0.72			-1.44	0.95	0.04	0.42	-0.52	1.53	-0.47	0.95	-0.17	0.52	0.30	1.63	0.46	1.53	0.01	0.49
VNIIM	1.55	0.91	1.53	1.11	1.44	0.95			1.48	0.95	0.92	1.75	0.97	1.27	1.27	0.99	1.74	1.84	1.90	1.75	1.44	0.98
NMI-VSL	0.07	0.32	0.06	0.72	-0.04	0.42	-1.48	0.95			-0.56	1.53	-0.50	0.95	-0.21	0.52	0.26	1.63	0.43	1.53	-0.03	0.49
GUM	0.63	1.51	0.62	1.63	0.52	1.53	-0.92	1.75	0.56	1.53			0.06	1.75	0.35	1.56	0.82	2.19	0.99	2.12	0.53	1.55
CEM	0.57	0.91	0.56	1.11	0.47	0.95	-0.97	1.27	0.50	0.95	-0.06	1.75			0.30	0.99	0.77	1.84	0.93	1.75	0.47	0.98
METAS	0.28	0.44	0.27	0.77	0.17	0.52	-1.27	0.99	0.21	0.52	-0.35	1.56	-0.30	0.99			0.47	1.65	0.64	1.56	0.18	0.57
CHMI	-0.19	1.61	-0.20	1.73	-0.30	1.63	-1.74	1.84	-0.26	1.63	-0.82	2.19	-0.77	1.84	-0.47	1.65			0.16	2.19	-0.29	1.65
FMI	-0.36	1.51	-0.37	1.63	-0.46	1.53	-1.90	1.75	-0.43	1.53	-0.99	2.12	-0.93	1.75	-0.64	1.56	-0.16	2.19			-0.46	1.55
IPQ	0.10	0.41	0.09	0.76	-0.01	0.49	-1.44	0.98	0.03	0.49	-0.53	1.55	-0.47	0.98	-0.18	0.57	0.29	1.65	0.46	1.55		

CCQM-K1.c, EUROMET.QM-K1.c and APMP.QM-K1.c
 Degrees of equivalence for NO in N₂ at nominal value 100 μmol/mol



Red diamonds : participants in CCQM-K1.c
Green triangles : participants in EUROMET.QM-K1.c
Blue circles : participants in APMP.QM-K1.c

Key comparison CCQM-K1.c

MEASURAND : Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N₂)

NOMINAL VALUE : 1000 µmol/mol

x_i : result of measurement carried out by laboratory i

u_i : combined standard uncertainty of x_i

$x_{i\text{grav}}$: gravimetric value of the NO amount-of-substance fraction in the cylinder received by laboratory i

$u_{i\text{grav}}$: combined standard uncertainty of $x_{i\text{grav}}$

Lab i	x_i / (µmol/mol)	u_i / (µmol/mol)	$x_{i\text{grav}}$ / (µmol/mol)	$u_{i\text{grav}}$ / (µmol/mol)	Date of measurement
NPL	1002.0	1.5	999.77	0.06	96-01
NIST	999.8	2.3	1000.00	0.06	95-06
NMi	1000.0	1.5	1000.60	0.06	95-04
BNM-LNE	1000.2	0.7	1000.10	0.06	96-01
KRISS	1000.1	1.1	1000.30	0.06	95-03
NRLM*	1002.6	2.5	1000.50	0.06	95-03
NRCCRM	1047.0	5.2	1000.80	0.06	95-04
VNIIM	1006.8	4.0	1000.90	0.06	95-04
OMH	1005.0	2.0	1001.20	0.06	95-06

*At the time of the comparison, NMIJ (National Metrology Institute of Japan) was designated as NRLM (National Research Laboratory of Metrology).

Key comparison CCQM-K1.c

MEASURAND : Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N₂)
 NOMINAL VALUE: 1000 µmol/mol

Key comparison reference value: there is no single reference value for this comparison,
 the value $x_{i\text{grav}}$ is taken as the reference value for laboratory i .

The degree of equivalence of each laboratory with respect to the reference value is given by a pair of terms:

$D_i = (x_i - x_{i\text{grav}})$ and U_i , its expanded uncertainty ($k = 2$), both expressed in µmol/mol

$$U_i^2 = 2^2(u_i^2 + u_{i\text{grav}}^2)$$

The degree of equivalence between two laboratories is given by a pair of terms:

$D_{ij} = D_i - D_j = (x_i - x_{i\text{grav}}) - (x_j - x_{j\text{grav}})$ and U_{ij} , its expanded uncertainty ($k = 2$), both expressed in µmol/mol

$$U_{ij} = 2(u_i^2 + u_j^2 + u_{i\text{grav}}^2 + u_{j\text{grav}}^2)^{1/2}$$

Lab j \longrightarrow

Lab i \downarrow

	D_i U_i / (µmol/mol)		NPL		NIST		NMI		BNM-LNE		KRISS		NRLM		NRCCRM		VNIIM		OMH	
	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
NPL	2.23	3.01			2.43	5.58	2.83	4.25	2.13	3.32	2.43	3.73	0.13	5.85	-43.97	10.89	-3.67	8.50	-1.57	5.02
NIST	-0.20	4.70	-2.43	5.58			0.40	5.58	-0.30	4.90	0.00	5.19	-2.30	6.87	-46.40	11.48	-6.10	9.24	-4.00	6.18
NMI	-0.60	3.00	-2.83	4.25	-0.40	5.58			-0.70	3.31	-0.40	3.72	-2.70	5.84	-46.80	10.89	-6.50	8.50	-4.40	5.02
BNM-LNE	0.10	1.41	-2.13	3.32	0.30	4.90	0.70	3.31			0.30	2.61	-2.00	5.20	-46.10	10.56	-5.80	8.08	-3.70	4.26
KRISS	-0.20	2.20	-2.43	3.73	0.00	5.19	0.40	3.72	-0.30	2.61			-2.30	5.47	-46.40	10.70	-6.10	8.25	-4.00	4.58
NRLM	2.10	5.01	-0.13	5.85	2.30	6.87	2.70	5.84	2.00	5.20	2.30	5.47			-44.10	11.61	-3.80	9.40	-1.70	6.43
NRCCRM	46.20	10.47	43.97	10.89	46.40	11.48	46.80	10.89	46.10	10.56	46.40	10.70	44.10	11.61			40.30	13.15	42.40	11.22
VNIIM	5.90	7.95	3.67	8.50	6.10	9.24	6.50	8.50	5.80	8.08	6.10	8.25	3.80	9.40	-40.30	13.15			2.10	8.91
OMH	3.80	4.02	1.57	5.02	4.00	6.18	4.40	5.02	3.70	4.26	4.00	4.58	1.70	6.43	-42.40	11.22	-2.10	8.91		

CCQM-K1.c

Degrees of equivalence for NO in N₂ at nominal value 1000 μmol/mol

