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

Key comparison CCQM-K1.c

MEASURAND :   **Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N_2)**
NOMINAL VALUE :   **100 µmol/mol**

x_i: **result of measurement carried out by laboratory i**

u_i: **combined standard uncertainty of x_i**

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

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

Lab i	x_i / (µmol/mol)	u_i / (µmol/mol)	$x_{i\,grav}$ / (µmol/mol)	$u_{i\,grav}$ / (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 (National Metrology Institute of Japan) was designated
as NRLM (National Research Laboratory of Metrology).

Key comparison EUROMET.QM-K1.c

MEASURAND :   **Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N_2)**
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

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

MEASURAND :   Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N_2)

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 $x_{i\,grav}$ 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:

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

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

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

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

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

Key comparison EUROMET.QM-K1.c

The gravimetric value $x_{i\,grav\text{-}EUR}$ 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:

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

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

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 / (µmol/mol)	U_i / (µmol/mol)	$D_{i\text{-EUR}}$ / (µmol/mol)	$U_{i\text{-EUR}}$ / (µmol/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:

$D_i = D_{i\text{-EUR}}$ **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:

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

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

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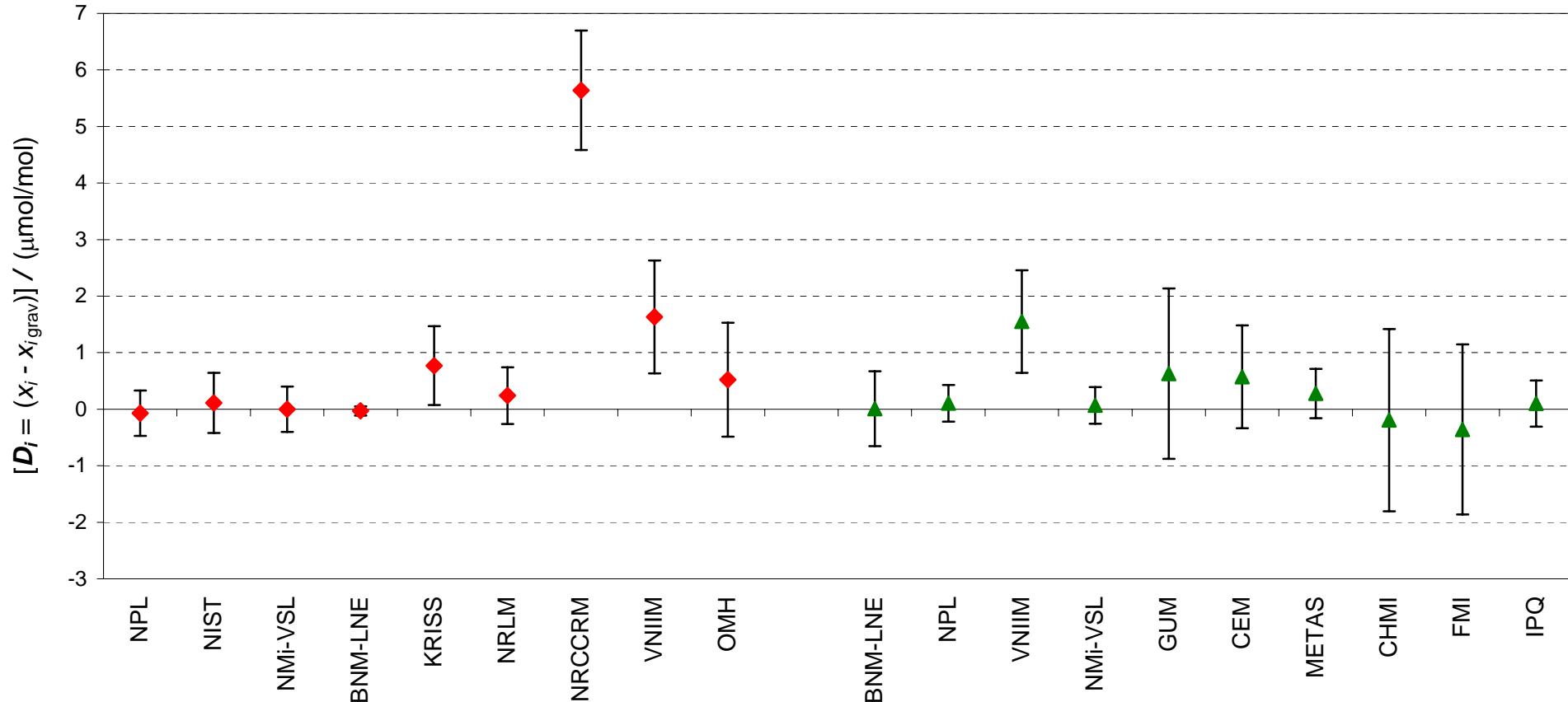
Key comparisons CCQM-K1.c and EUROMET.QM-K1.c

Matrix of Equivalence (1/2)

Lab _j_ ⟹

Lab _i_ ⟱

Lab i	D_i	U_i	NPL D_{ij}	U_{ij}	NIST D_{ij}	U_{ij}	NMi-VSL D_{ij}	U_{ij}	BNM-LNE D_{ij}	U_{ij}	KRISS D_{ij}	U_{ij}	NRLM D_{ij}	U_{ij}	NRCCRM D_{ij}	U_{ij}	VNIIM D_{ij}	U_{ij}	OMH D_{ij}	U_{ij}
	/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)	
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

Matrix of Equivalence (2/2)

Lab j ⟹

Lab i ⇓

Lab i	D_i	U_i	BNM-LNE D_{ij}	U_{ij}	NPL D_{ij}	U_{ij}	VNIIM D_{ij}	U_{ij}	NMi-VSL D_{ij}	U_{ij}	GUM D_{ij}	U_{ij}	CEM D_{ij}	U_{ij}	METAS D_{ij}	U_{ij}	CHMI D_{ij}	U_{ij}	FMI D_{ij}	U_{ij}	IPQ D_{ij}	U_{ij}
	/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)	
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 and EUROMET.QM-K1.c

Degrees of equivalence for NO in N_2 at nominal value 100 µmol/mol

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

Key comparison CCQM-K1.c

MEASURAND :   **Amount-of-substance fraction of Nitrogen monoxide (NO) in Nitrogen (N_2)**
NOMINAL VALUE :   **1000 µmol/mol**

x_i: **result of measurement carried out by laboratory i**

u_i: **combined standard uncertainty of x_i**

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

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

Lab i	x_i / (µmol/mol)	u_i / (µmol/mol)	$x_{i\,grav}$ / (µmol/mol)	$u_{i\,grav}$ / (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 (N_2)
NOMINAL VALUE: 1000 µmol/mol

Key comparison reference value: there is no single reference value for this comparison, the value $x_{i\,grav}$ 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:
$D_i = (x_i - x_{i\,grav})$ and U_i, its expanded uncertainty ($k = 2$), both expressed in µmol/mol
$U_i^2 = 2^2(u_i^2 + u_{i\,grav}^2)$

The degree of equivalence between two laboratories is given by a pair of terms:
$D_{ij} = D_i - D_j = (x_i - x_{i\,grav}) - (x_j - x_{j\,grav})$ and U_{ij}, its expanded uncertainty ($k = 2$), both expressed in µmol/mol
$U_{ij} = 2(u_i^2 + u_j^2 + u_{i\,grav}^2 + u_{j\,grav}^2)^{1/2}$

Lab j ⟹

Lab i	D_i	U_i	NPL D_{ij}	NPL U_{ij}	NIST D_{ij}	NIST U_{ij}	NMi D_{ij}	NMi U_{ij}	BNM-LNE D_{ij}	BNM-LNE U_{ij}	KRISS D_{ij}	KRISS U_{ij}	NRLM D_{ij}	NRLM U_{ij}	NRCCRM D_{ij}	NRCCRM U_{ij}	VNIIM D_{ij}	VNIIM U_{ij}	OMH D_{ij}	OMH U_{ij}
	/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)		/ (µmol/mol)	
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 N_2 at nominal value 1000 μmol/mol

Y-axis: $[D_i = (x_i - x_{i\,grav})] / (\mu$mol/mol$)$

X-axis labels: NPL, NIST, NMi, BNM-LNE, KRISS, NRLM, NRCCRM, VNIIM, OMH