

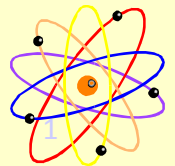
CCM Report to CGPM

(2008-2011)

Dr. Mitsuru Tanaka
President, CCM



Paris, October 2011

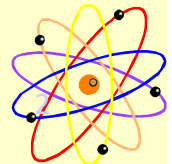


CCM \Rightarrow Mass and Related Quantities

- ❖ Mass(kg),
- ❖ Density(kg/m³),
- ❖ Force(N),
- ❖ Pressure(Pa) (incl. Vacuum),
- ❖ Hardness(hardness scale),
- ❖ Fluid Flow(m³/s, kg/s),
- ❖ Viscosity(Pa · s),
- ❖ Gravity(m/s²)

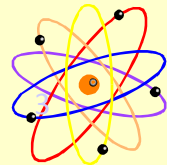
Activities of CCM

- ❖ Improvement of Global Measurement Standard,
- ❖ Key Comparison / CIPM-MRA,
- ❖ SI-kg, Avogadro constant,
- ❖ Recommendation G1(2010) + G2(2010),
- ❖ Re-definition of kilogram



Contents

0. Structure and administration
1. Progress of Key Comparisons: CCM. *-K**
2. Progress of Avogadro Program: N_A
3. Preparation for Re-definitions: *mise en pratique*
4. Improvements of global measurement standard



0. Structure and administration

WGM: mass: 2008, 2010, 2011

TG1: 1kg in vacuum: 2008, 2010, 2011 (**new**)

TG2: uncertainty of 1kg: 2008, 2010, 2011 (**new**)

WGD: density: 2008, 2011

WGF: force: 2007, 2011

WGHP: hi-pressure: 2008, 2011 (**new chair**)

WGLP: vacuum: 2008, 2011

WGAC: Avogadro constant: 2008, 2009, 2010, 2011 (**new chair**)

IAC: Enriched Silicon: 2008, 2009, 2010, 2011 (**finish, new MoU**)

WGH: hardness: 2007, 2008, 2009, 2010, 2011

WGFF: fluid flow: 2007, 2008, 2009, 2010, 2011 (**new chair**)

WGG: gravity: 2010, 2011 (**new assign**)

WGV: viscosity: 2008, 2011 (**new chair**)

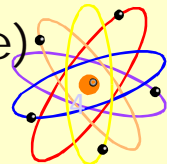
WGS1kg: re-definition: 2010, 2011

WGCMC: CMCs : 2008, 2011

Chairs meeting: WGKC: 2008, 2010, 2011

CCM meeting: 2008, 2010(&WS kg), 2011(&Conf. Pressure)

(**R.Davis** → **A.Picard**)



0. Structure and administration

Members of CCM: (22)

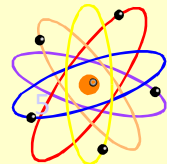
BEV, GUM, CEM, CENAM, VNIIM,
METAS, I.N.Ri.M, KRISS, LNE, MSL,
NIM, NIST, NMIA, NMIJ/AIST, NMISA,
NPL, NPLI, NRC-INMS, PTB, SMU,
SP, VSL

Observers: (4)

A*STAR, IPQ, LATU, UME

RMO: (5xTCM+3xTCFF)

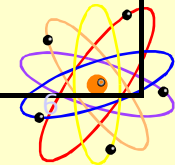
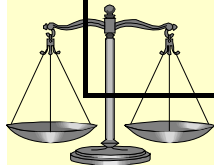
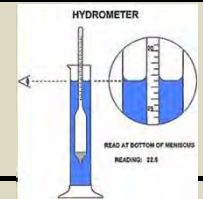
APMP, COOMET, EURAMET, AFRIMET, SIM



CCM Progress Report for 2008-2011



1. Progress of Key Comparisons

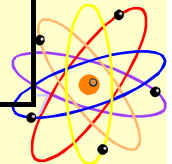
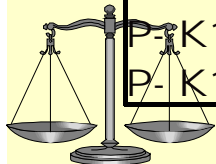
	2007	2011	APMP	COOMET	EURAMET	AFRIMET	SIM
M- K1	Compl.	Compl.	Compl. 4	Compl. 1	Compl. 6	Calib 2	Compl. 6
M- K2	Compl.	Compl.	Plan 4	DraftA 1	DraftB 3		Calib 2
M- K3	Compl.	Compl.					DraftB 2
M- K3.1		Compl.					P-col 1
M- K4	DraftA	Plan					
M- K5	DraftB	Compl.					
M- K6		P-col.					
M- K7		Plan					
				TOTAL 32			
D- K1	Compl.	Compl.	Cal 1		Compl. 3		Compl. 4
D- K2	DraftA	DraftB			DraftB 1		Cal 1
D- K3	Plan	Plan			Cal 2		
D- K4	Plan	Cal					
				TOTAL 12			
F- K1.a	DraftB	Compl.	DraftB 1	Cal 1	Compl. 1		P-col 1
F- K1.b	DraftB	Compl.	Cal 2		DraftB 2		
F- K2.a	DraftA	DraftB	Plan 2		Cal 1		
F- K2.a.1		Plan					
F- K2.b	DraftA	DraftB					
F- K3.a	DraftA	DraftA					
F- K3.b	Cal	DraftA					
F- K4.a	DraftA	DraftB					
F- K4.b	DraftA	DraftB					
F- K5-F.K22	Compl.	Compl. Provis.					
				TOTAL 11			



CCM Progress Report for 2008-2011

1. Progress of Key Comparisons

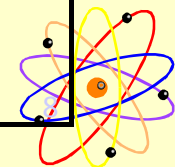
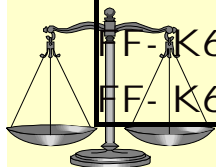
T- K1	DraftA	Compl.				Compl. 2	
T- K1.1		Compl.				DraftA 1	
T- K1.2		DraftA					
T- K1.3		Cal					
T- K2	Cal	Cal				TOTAL 3	
P- K1.a	Compl.	Compl.	Compl 11	Compl 2	Compl 12	Compl 2	
P- K1.b	Compl.	Compl.	Cal 5	Cal 1	Prov 2	DraftB 2	
P- K1.c	Compl.	Compl.	P-col 1		DraftB 1	DraftA 1	
P- K2	DraftA	Compl.	Plan 1		Plan 2	Cal 3	
P- K3	DraftA	Compl.				P-col 3	
P- K3.1		P--col.				Plan 3	
P- K4	DraftB	Compl.					
P- K5	DraftB	Compl.					
P- K6	DraftB	Compl.					
P- K7	DraftB	Compl.					
P- K8	DraftA	Compl.					
P- K9		Compl.					
P- K10		Compl.					
P- K11		Compl.					
P- K12	Cal	DraftB					
P- K13		DraftA					
P- K14		DraftA					
P- K14.1		P-col.					
			TOTAL 52				





CCM Progress Report for 2008-2011

1. Progress of Key Comparisons

H- K1.a	Compl.	Compl.	Compl.	2	Compl.	1		
H- K1.b	Compl.	Compl.	DraftA	1	DraftB	2		
H- K1.c	Compl.	Compl.	Cal.	2	P-col.	2		
H- K2	DraftB	DraftA						
H- K3		Plan						
TOTAL 10								
FF- K1	Compl.	Compl.	Compl	4	Compl	1	Compl	4
FF- K2	Cal	Compl.	DraftA	1	DraftA	2	Cal	1
FF- K2.1. '11		P-col.	Plan	1	Cal	1	P-col	1
FF- K3	Compl.	Compl.						
FF- K3. '11		Plan						
FF- K4	Compl.	Compl.						
FF- K4.1. '11		P-col						
FF- K4.2. '11		P-col						
FF-K5. '11		Plan						
FF- K5.a	Compl.	Compl.						
FF-K5.a.1		Compl.						
FF-K5.a.2		Plan						
FF- K5.b	Compl.	Compl.						
FF- K6	DraftA	Compl.						
FF- K6. '11		P-col						
TOTAL 19								



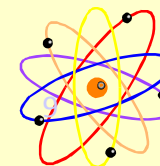
1. Progress of Key Comparisons

V- K1.a	Compl.	Compl.	Compl	1	Compl	4	Compl	1
V- K1.b1	Compl.	Compl.	 <p>TOTAL 6</p>					
V- K1.b2	Compl.	Compl.						
V- K1.b3	Compl.	Compl.						
V- K1.c	Compl.	Compl.						
V- K2.1		Compl.						
V- K2.a	DraftA	Compl.						
V- K2.b	DraftB	Compl.					 <p>TOTAL 2</p>	
G- K1		DraftA	Compl	1				
G-P	DraftA		Plan	1				

Key Comparisons, managed by WGs and harmonized by CCM Chairs meeting.

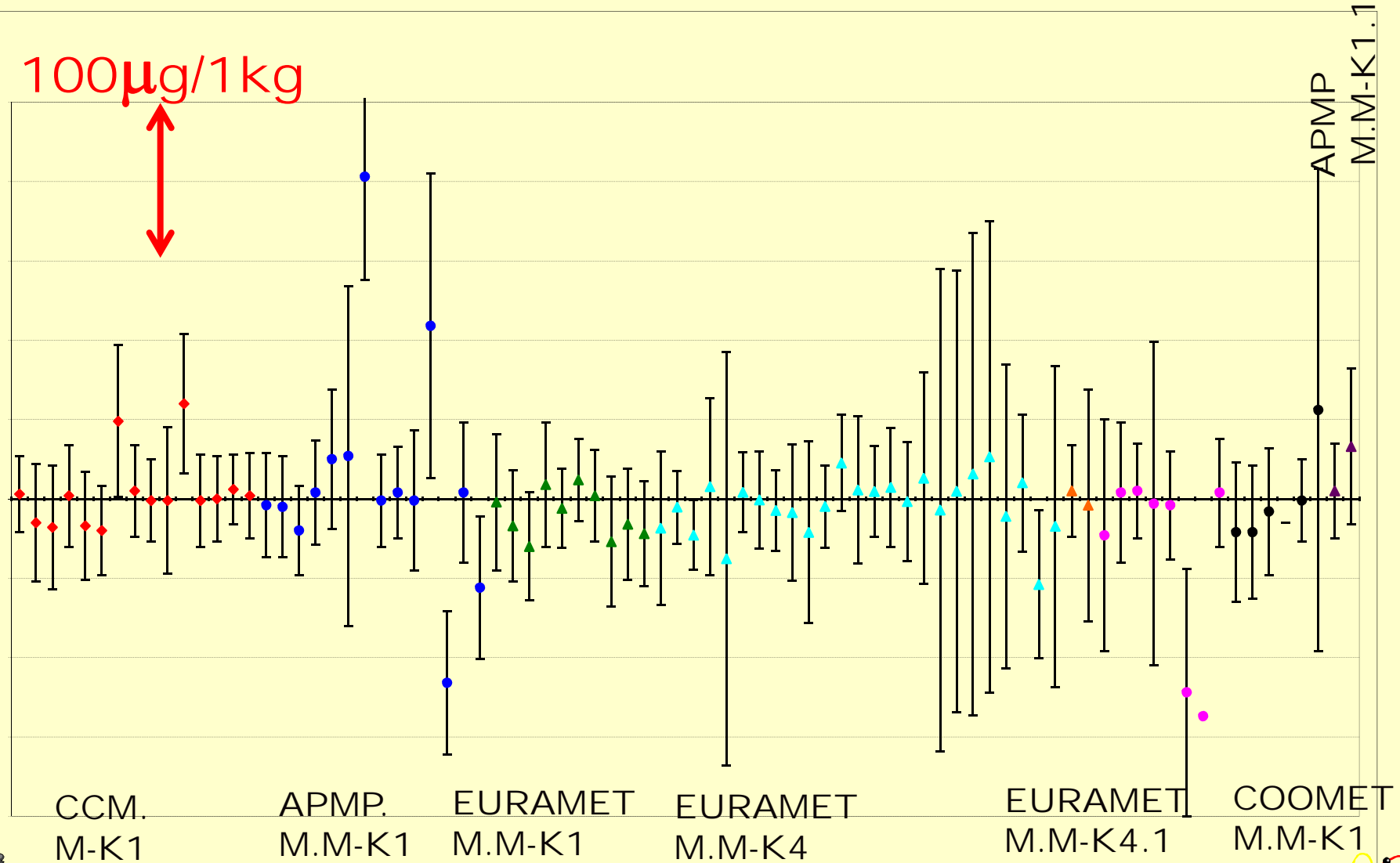
WGCMC was consulted on 10 CMC issues, in M, D and F.

- ❖ User friendly and simple CMC format.
- ❖ Period of Key Comparisons.
- ❖ Stability of Transfer standards.
- ❖ Level of calibration services
- ❖ Guide to search supporting KCs

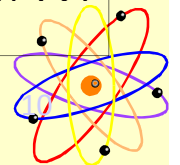


1. Progress of Key Comparisons

100 $\mu\text{g}/1\text{kg}$



CCM.M-K4 is started .

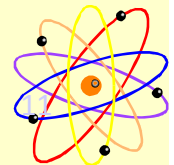
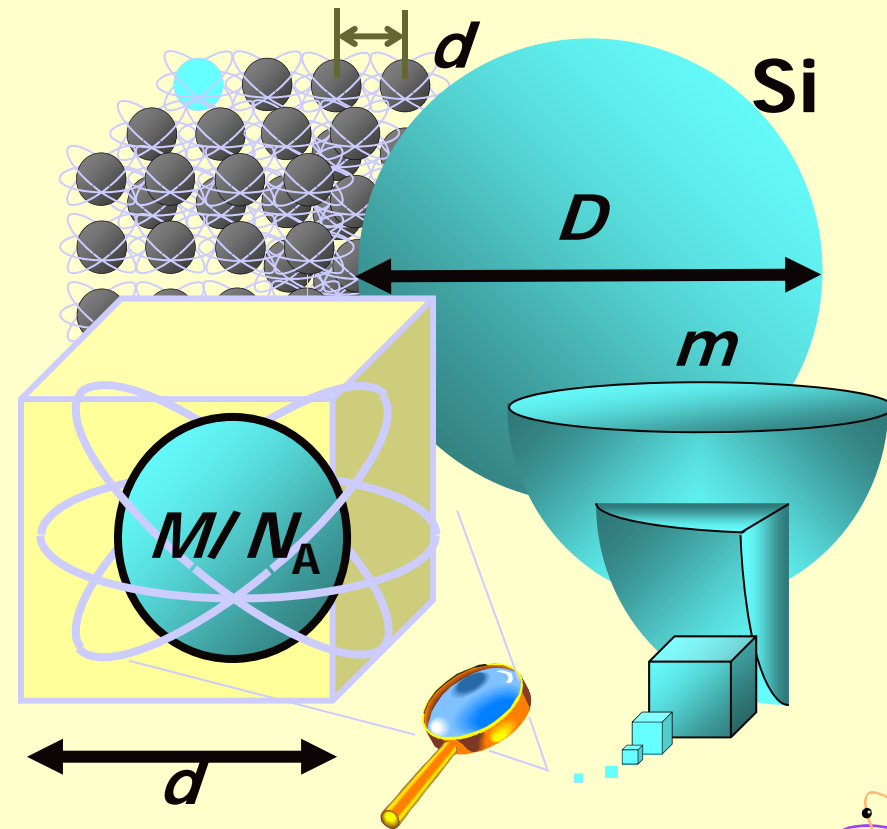


2. Progress of Avogadro Program

Micro. Density = Macro. Density

$$(8M/N_A) / d^3 = \rho = 6m/\pi D^3$$

$$N_A = M / (8^{1/2} \times \rho \times d_{220}^3)$$



2. Progress of Avogadro Program



Special issue of Metrologia:
International determination of the Avogadro constant
Metrologia, Volume 48 (April 2011)

$$N_A = 6.022\,140\,78(18) \times 10^{23} \text{ mol}^{-1}$$

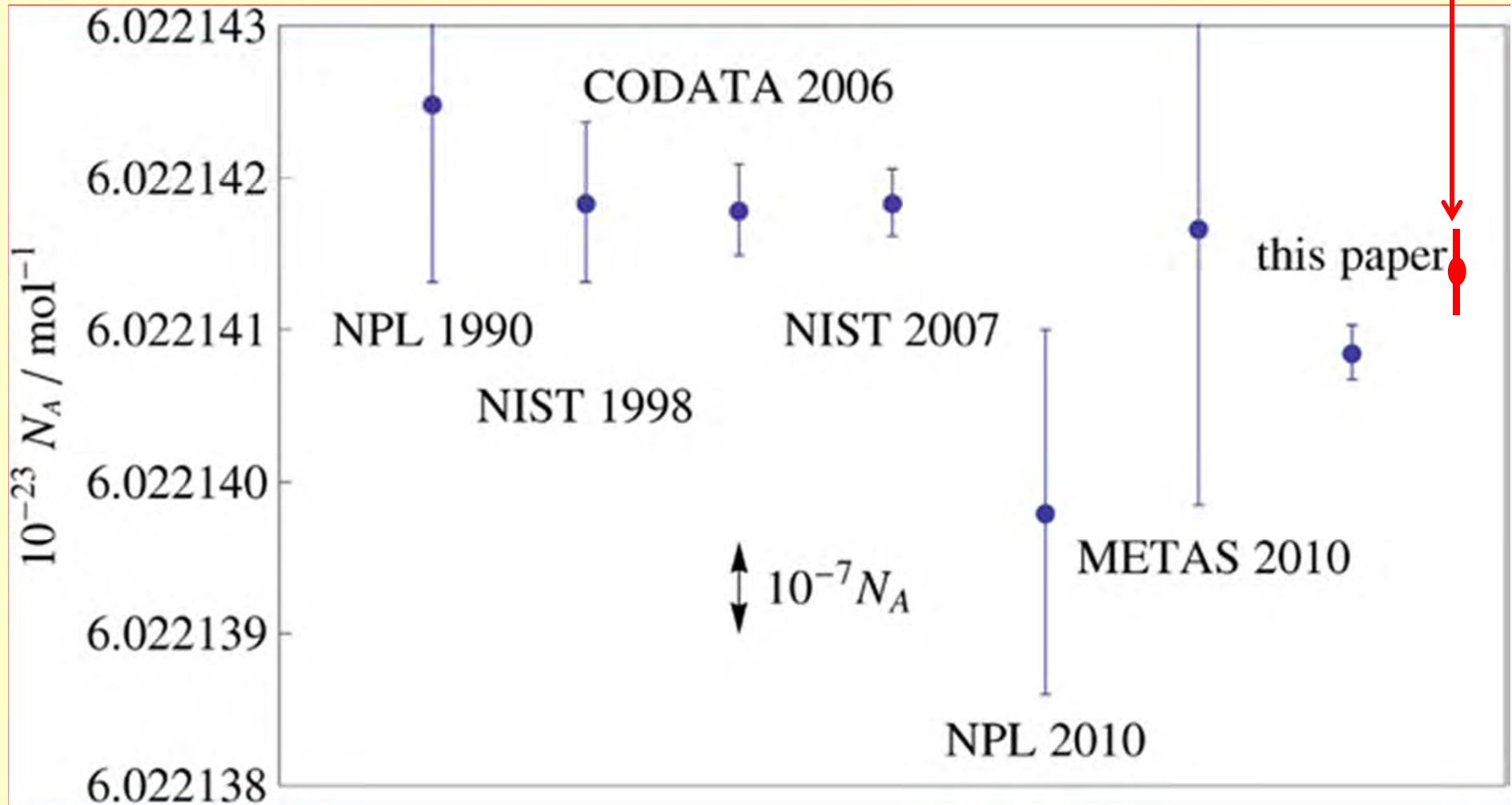
TABLE III. N_A determination. Lattice parameter, volume, and density are measured at 20.0 °C and 0 Pa.

Quantity	Unit	AVO28-S5	AVO28-S8
a	pm	543.099 6240(19)	543.099 618 5(20)
m	g	1000.087 560(15)	1000.064 543(15)
V	cm ³	431.059059(13)	431.049 110(10)
ρ	kg/m ³	2320.070 855(76)	2320.071 007(63)
M	g/mol	27.976 970 26(22)	27.976 970 29(23)
N_A	10 ²³ mol ⁻¹	6.022 140 91(21)	6.022 140 71(18)

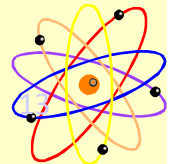


2. Progress of Avogadro Program

CODATA 2010 : $6.022\,141\,29(27) \times 10^{23} \text{ mol}^{-1}$



Metrologia 48 (2011) S1-S13
"Counting the atoms in a ^{28}Si crystal
for a new kilogram definition", B. ANDREAS, et al.



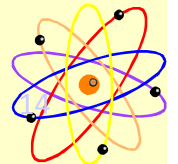
2. Progress of Avogadro Program

1992- WG Avogadro Constant

2003–2011 Int'l Avogadro Coordination (IAC)
PTB, I.N.Ri.M, IRMM, BIPM,
NPL, NIST, NMIA, NMIJ/AIST

Creation Enriched ^{28}Si +Crystal Growth
+Sphere Polishing +Molar Mass
+Surface Contamination

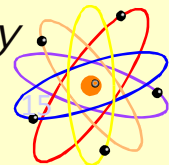
2011- New MoU for Cooperation to determine the
Avogadro Constant
+EURAMET Proj.+Other NMIs



3. Preparation for Re-definitions

Present system		After redefinition		
		Ex. 1 (CCM req.)	Ex. 2	Ex. 3
0 μg	Best realisation of the kilogram	20 μg	30 μg	50 μg
	BIPM reference standards	30 μg	42 μg	71 μg
6 μg	BIPM Working standards	30 μg	43 μg	71 μg
6 μg	National standards of NMIs	30 μg	43 μg	71 μg
14 μg	Secondary standards of NMIs and best standards according to CMC	32 μg	43 μg	71 μg
25 μg	Reference standards of E_1 accredited laboratories	44 μg	53 μg	77 μg
$\leq 83 \mu\text{g} (E_1)$	Standards of customers of E_1 accredited laboratories	$\leq 83 \mu\text{g} (E_1)$	85 $\mu\text{g} (E_2)$	100 $\mu\text{g} (E_2)$

From Workshop on the redefinition of the kilogram, 2010, CCM, "Redefinition of the kilogram, CCM recommendation and uncertainty propagation" by M. Glaeser, M. Borys, D. Ratschko, R. Schwartz



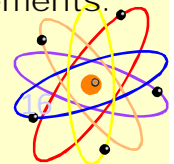
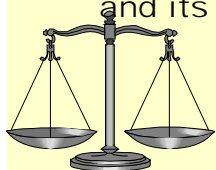
3. Preparation for Re-definitions

RECOMMENDATION G 1 (2010): *recommends*: that the following conditions be met before the kilogram is redefined in terms of fundamental constants:

1. At least **three independent experiments**, including work both from **watt balance** and from **International Avogadro Coordination** projects, yield values of the relevant constants with relative standard uncertainties not larger than **5 parts in 10^8** .
At least **one of these results** should have a relative standard uncertainty not larger than **2 parts in 10^8** ,
2. For each of the relevant constants, values provided by the different experiments be **consistent at the 95 % level** of confidence,
3. **Traceability of BIPM prototypes** to the international prototype of the kilogram be confirmed,

RECOMMENDATION G 2 (2010) On the use of the international prototype of the kilogram to confirm the traceability of the BIPM prototypes.

referring: to its Recommendation CCM G 1 (2010) which contained a specific recommendation that the traceability of the BIPM prototypes to the international prototype of the kilogram should be confirmed,
recommends: that the CIPM gives the Director of the BIPM **authority to gain access to the vault** containing the international prototype and its official copies and to make use of these prototypes in order to carry out the necessary measurements.



3. Preparation for Re-definitions

1. Wording of the *Mise en pratique* of the new definition of the kilogram (in progress)

2. Primary realization(s) of the definition of the kilogram

2.1. Realization by comparing electrical power to mechanical power

2.2. Realization by the X-ray-crystal-density (XRCD) method

2.3. Other realizations

3. Dissemination of the kilogram

3.1 (Dissemination from particular NMIs and BIPM primary realizations!!)

3.2 Dissemination based on an ensemble of mass standards (EMS) linked to a weighted mean (reference value) deduced from primary realization key comparison

3.2.1 Constitution and maintenance of an ensemble of mass standards

3.2.2 Computation and use of a weighted mean of the mass standards constituting the ensemble

3.3 Dissemination from NMIs and BIPM by taking into account the degree of equivalence based on the primary realizations key comparison

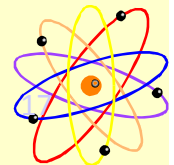
4 Continuity with previous kilogram definition

.....

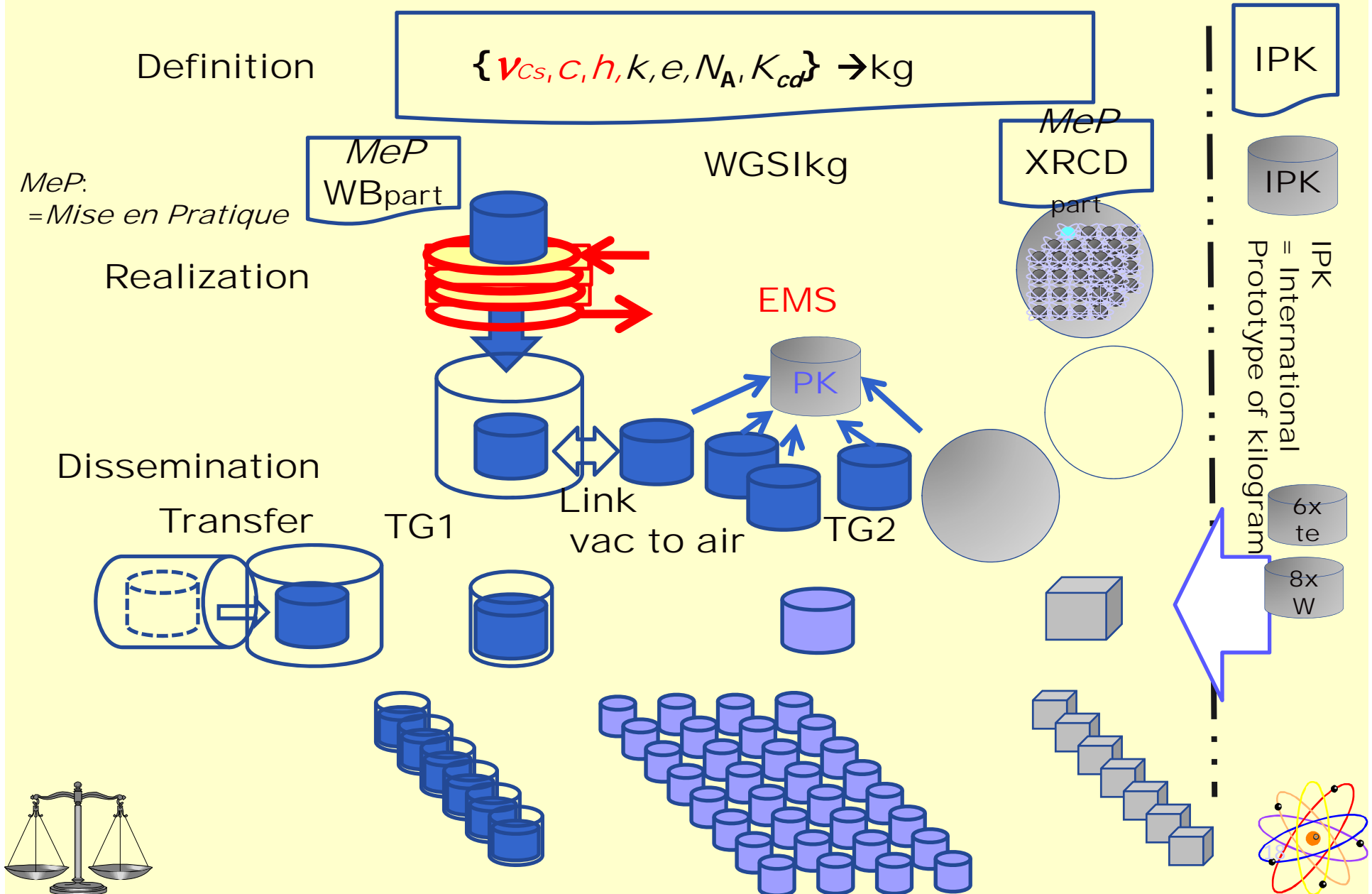
ANNEXES: Meeting experimental challenges in mass metrology

A.1 Vacuum-to-air mass transfers

A.2 List of relevant watt balances and XRCD experiments



3. Preparation for Re-definitions



3. Preparation for Re-definitions

The CCM WGS1kg task group 1:

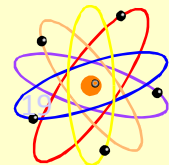
“Mass metrology under vacuum for a *Mise en Pratique*”

1. Comparison measurements on **watt balance test masses** and **silicon spheres of the IAC**,
2. Requirements on **mass metrology under vacuum**,
3. Activities and projects of TG 1 members in the field of mass metrology under vacuum/surface studies,
4. Present and future projects in the RMOs relevant for the work of the TG 1,
5. **TG 1 comparison for the air/vacuum transfer and the mass determination under vacuum.**

The CCM WGS1kg task group 2

“Uncertainty components due to traceability to the international prototype of the kilogram”

1. The **present uncertainty** to which the unit of mass can be **disseminated from the international to the national prototypes**;
2. Methods for evaluating the correlation between the measured mass values of the prototypes of the kilogram;
3. Recommendations for additional measurements, which would allow an improved uncertainty evaluation. These measurements may **involve use of the international prototype or its official copies**;



4. Improvements of global measurement standard

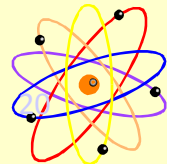
Terms of reference prepared by WGs.

Mass: Vacuum balance, Mass artefacts in vacuum, Cleaning technology, Transfer technology, Application of new air density formula.

Density: Water density table over 40 °C (IAPWS), New absolute measurement, Strategic plan (Foods, Environments), Volume measurement of Acoustic resonator for k .

Force: Stability and reproducibility of force transducers, Torque measurement standards. Strategic plan (small force, multi-component force, parasitic force components, dynamic force)

Pressure: Boundary of WGs at 1kPa, Pressure & Vacuum conference, Leak standard, Pressure measurement of Acoustic resonator for k .



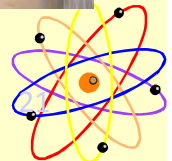
4. Improvements of global measurement standard

Hardness: New definition of Rockwell C scale → Brinell, Vickers. Comparison for indenter.

Fluid Flow: Cost of KC! Improvement of transfer standards. Uncertainty checklist for assessors. Uncertainties inherent to device under test.

Viscosity: Absolute viscosity measurement, non-Newtonian fluids, under high pressure and temperature.

Gravity: Testing capability of gravimetry + CMC, Management of KC with proposed new testing sites Luxemburg (2013), St.Peterburg, Beijin. Cooperation with Int'l Assoc. Geodesy (IAG).



Thank You

