



Bureau International des Poids et Mesures



Units for the Universe

or

The Metre Convention and its role in the 21st Century

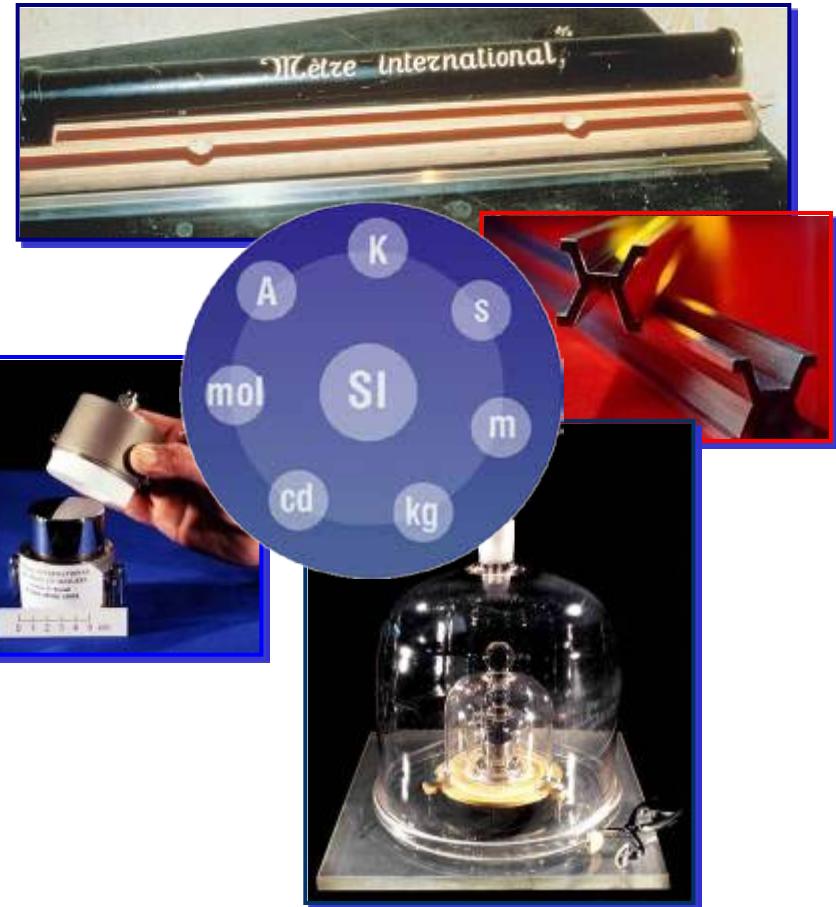
Professor Michael Kühne

Director, BIPM

Brief history of the Metre Convention and the SI

The Metre Convention and the SI

- ⊕ **20 May 1875** - The Metre Convention was signed in Paris by 17 nations. It established the BIPM which is a permanent organizational structure for member governments to act in common accord on all matters relating to units of measurement.
- ⊕ **1889** - the international prototypes for the metre and the kilogram, together with the astronomical second as unit of time, create the first international system of units.
- ⊕ **1954** - the ampere, kelvin and candela are added as base units.
- ⊕ **1960** - the unit system is named as the International System of Units (SI)
- ⊕ **1971** - the mole is added as the unit for amount of substance, bringing the total number of base units to seven.



Bureau International des Poids et Mesures

BIPM

Headquartered in Paris, France and **financed** by supporting governments.



Maintains **scientific laboratories** in areas of: mass, time, electricity, ionizing radiation, and chemistry.

CIPM



Made up of **eighteen individuals**, different nationalities.

Meets annually to promote worldwide uniformity in units of measurement.

Is the **management board** for the BIPM

CGPM

Made up of **representatives** from Member States.

Meets in Paris typically **every four years** to discuss the status of international metrology.



Bureau International des Poids et Mesures

The BIPM

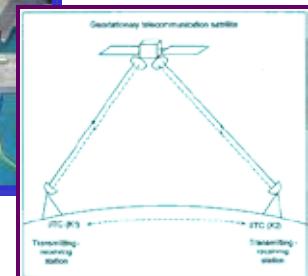
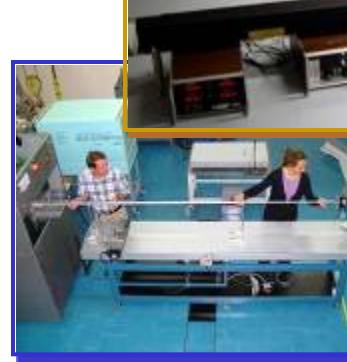
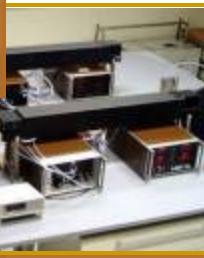
It has **headquarters** near Paris, France. It is **financed** jointly by the Member States and Associates, and operates under the exclusive **supervision** of the CIPM.

Its **mandate** is to provide the basis for a single, coherent system of measurements throughout the world, traceable to the International System of Units (SI). This task takes many forms, from **direct dissemination** of units (as in the case of mass and time) to coordination through **international comparisons** of national measurement standards (as in electricity and ionizing radiation).

It maintains **laboratories** in areas of: mass, time, electricity, ionizing radiation, and chemistry.

It has an international **staff** of around 75.

Its **budget** for 2012 is around twelve million euros.



BIPM's main technical roles

Maintains the kilogram for the near future (until redefinition).

Creates and disseminates Coordinated Universal Time (UTC) based on weighted averages of ~ 200 clocks from over 50 National laboratories worldwide.

Maintains unique world reference facilities e.g., SIR (ionizing radiation and isotopes), ozone spectrophotometers.

Maintains travelling standards to compare fixed national references e.g., Josephson Junctions for the volt, Quantum Hall devices for the ohm, etc.

Coordinates international comparisons and networks e.g., organic chemistry reference materials for laboratory medicine.

Promotes traceable, accurate measurement for physical, engineering, chemical and medical quantities worldwide.

BUREAU INTERNATIONAL DES POIDS ET MESURES

The Pavillon de Breteuil
when given to the BIPM in
1870



Bureau International Des Poids Et Mesures



The Pavillon de Breteuil
today



Comité International des Poids et Mesures

The CIPM

Is made up of eighteen individuals, each from a different State. Its principal task is to promote worldwide uniformity in units of measurement by direct action or by submitting draft resolutions to the CGPM.

Meets annually and, its duties include:

- ⊕ consideration of the work of the BIPM;
- ⊕ consideration of reports presented to it by its Consultative Committees;
- ⊕ consideration of metrological work that Member States decide to do in common and sets up and coordinates activities between specialists in metrology;
- ⊕ making appropriate Recommendations;
- ⊕ issuing an Annual Report on the administrative and financial position of the BIPM to the Member States;
- ⊕ commissioning reports in preparation for CGPMs, and others such as the SI Brochure.

CIPM 1894



CIPM 2011

Conférence Générale des Poids et Mesures

The CGPM

Is made up of representatives of the governments of the Member States. Associates States and Economies of the CGPM can attend its meetings.

Meets in Paris typically every four years; the 24th meeting of the CGPM was held in October 2011, the 25th meeting will be in Autumn 2014

At each meeting

- ⊕ it receives a report of the International Committee for Weights and Measures (CIPM) on work accomplished
- ⊕ it discusses and examines the arrangements required to ensure the propagation and improvement of the International System of Units (SI)
- ⊕ it endorses the results of new fundamental metrological determinations and various scientific resolutions of international scope; and
- ⊕ it decides all major issues concerning the organization and development of the BIPM, including the budget of the BIPM for the next period.



Comité International des Poids et Mesures

The CIPM Consultative Committees

- CCAUV** Consultative Committee for **Acoustics, Ultrasound and Vibration**
- CCEM** Consultative Committee for **Electricity and Magnetism**
- CCL** Consultative Committee for **Length**
- CCM** Consultative Committee for **Mass and Related Quantities**
- CCPR** Consultative Committee for **Photometry and Radiometry**
- CCQM** Consultative Committee for Amount of Substance (**Chemistry**)
- CCRI** Consultative Committee for **Ionizing Radiation**
- CCT** Consultative Committee for **Thermometry**
- CCTF** Consultative Committee for **Time and Frequency**
- CCU** Consultative Committee for **Units**

Joint committees

**Committees of the BIPM and other international organizations,
created for particular tasks of common interest.**

JCTLM

Joint Committee for Traceability in Laboratory Medicine.



The goal of the JCTLM is to provide a worldwide platform to promote and give guidance on internationally recognized and accepted equivalence of measurements in laboratory medicine and traceability to appropriate measurement standards.

JCGM

Joint Committee for Guides in Metrology.

[BIPM](#), [IEC](#), [IFCC](#), [ILAC](#), [ISO](#), [IUPAC](#), [IUPAP](#), [OIML](#)

The tasks of the JCGM are to **maintain and promote the use** of the Guide to the Expression of Uncertainty in Measurement (known as the **GUM**) and the International Vocabulary of Basic and General Terms in Metrology (known as the **VIM**).

DCMAS Network

Network on Metrology, Accreditation and Standardization for Developing Countries.



THE CIPM MRA



In 1999, and in support of world trade, the CIPM established a Mutual Recognition Arrangement (MRA) of national measurement standards and of calibration and measurement certificates issued by NMIs. The aim of the CIPM MRA is to provide the technical basis for the worldwide acceptance of national

measurement standards and calibration and measurement certificates of NMIs.

Currently, CIPM MRA participants comprise of:

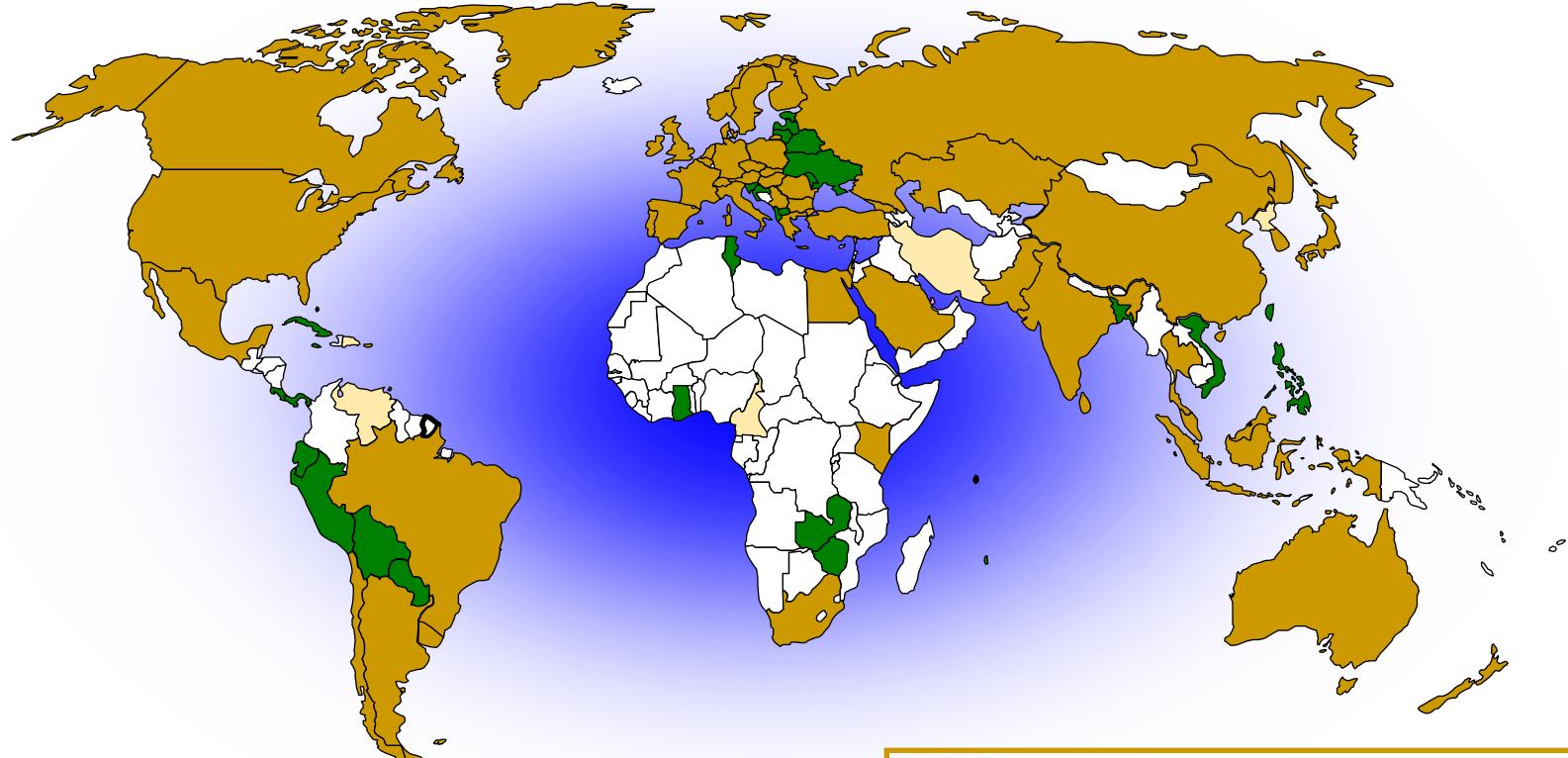
- ⊕ 50 Member States of the BIPM,
- ⊕ 3 International Organizations (IAEA, IRMM and WMO), and
- ⊕ 34 States/Economies that are Associates of the CGPM.

Participating NMIs meeting this criteria:

- ⊕ have implemented **quality/management systems** that govern their delivery of services (ISO/IEC 17025 or ISO Guide 34).
- ⊕ have their calibration and measurement capabilities (**CMCs**) peer reviewed and publicly declared in the BIPM
- ⊕ take part in **key comparisons** that validate their technical proficiency



CIPM MRA Participation



86 NMIs plus a further 138 designated institutes from
50 Member States
34 Associates of the CGPM
3 international organizations

[Legend]
■ Member participating in the CIPM MRA
■ Associate participating in the CIPM MRA

Challenges for the 21st century

At the beginning of the 21st century we have come close to fulfil a dream: To define all base units by means of fundamental constants.

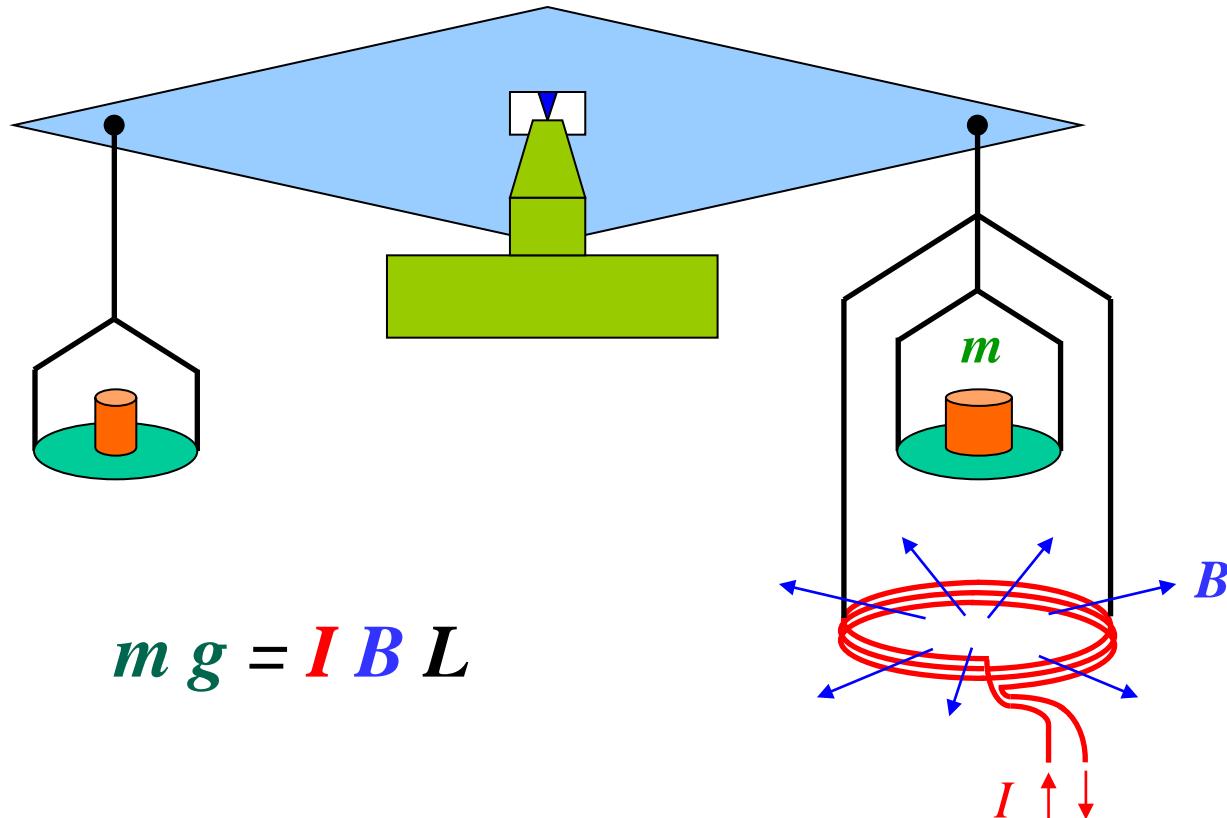
The re-definition of the kg, the ampere, the kelvin and the mole complete this dream.

While the 19th and the 20th century the core task of metrology was to provide and improve traceability for industry and science for the 21st century the challenge lies in fields of

- ⊕ **Metrology for climate change monitoring and the environment**
- ⊕ **Metrology for health, in particular for diagnostics and therapeutics as well as metrology for food safety**

How does a watt balance work?

1. Weighing phase:

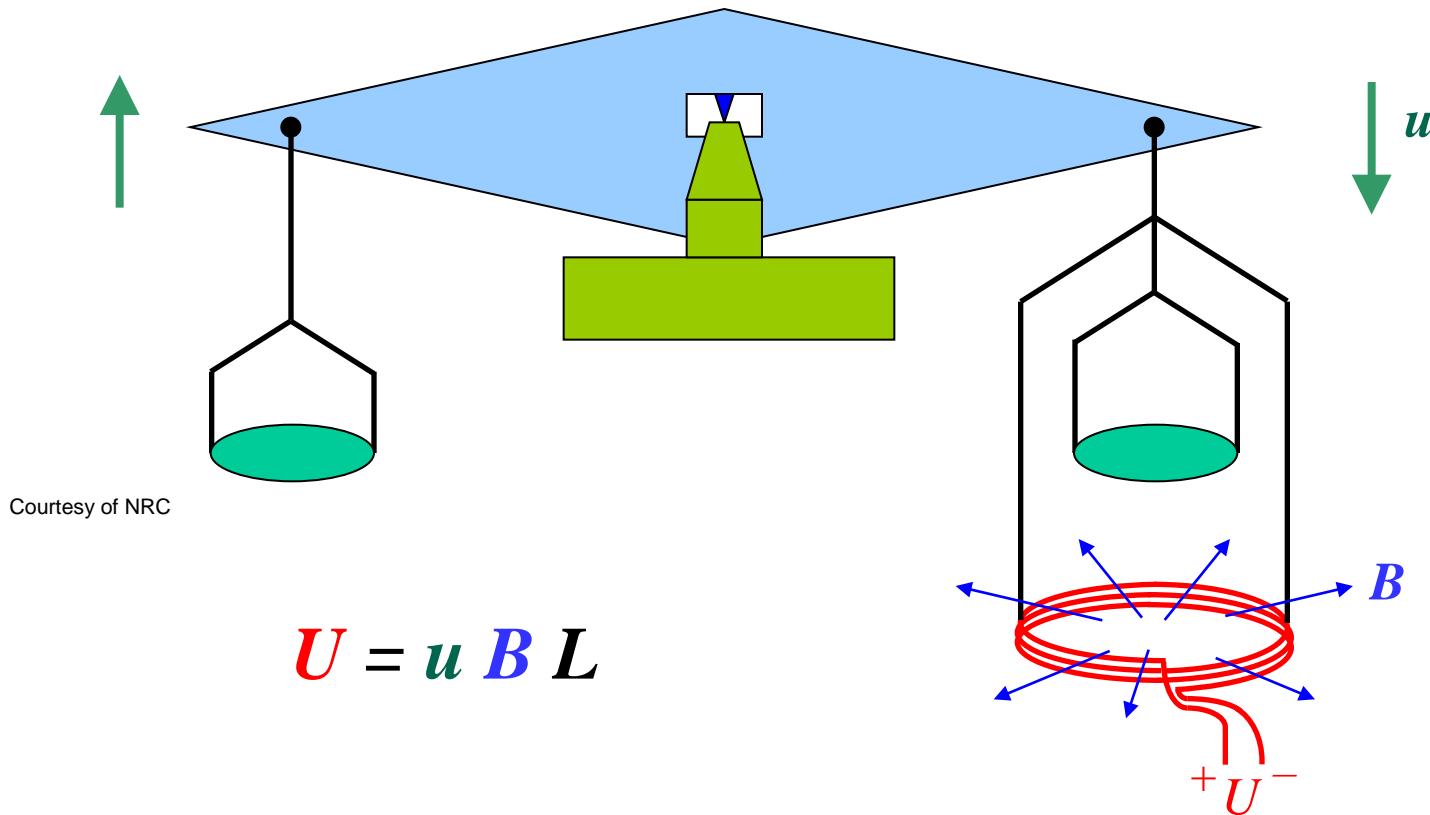


Courtesy of NRC

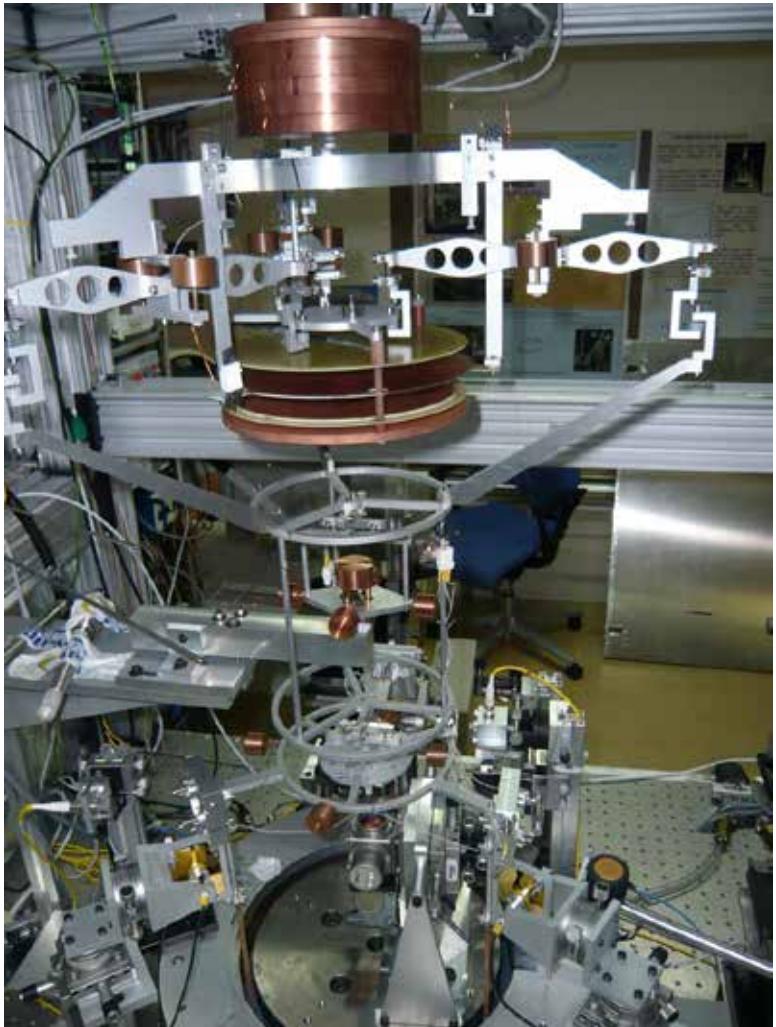
$$m g = I B L$$

How does a watt balance work?

2. Moving phase (move the coil through the magnetic field at velocity u and measure the induced voltage, U).



The BIPM watt balance



Present status

- “complete” experiment: h measurements can be carried out
- dedicated laboratory with vibration isolation ready
- relative and absolute (ICAG-2009) determination of g
- study on cryogenic watt balance started
- recently changed to 3-axis interferometer

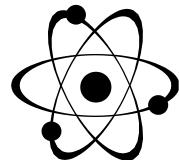
2011-2012

- move to dedicated laboratory
- install final magnet
- install mass exchanger and coil position control unit
- install vacuum system
- use improved alignment system to reduce type B unc.

Target uncertainty end 2012: $< 1 \times 10^{-6}$

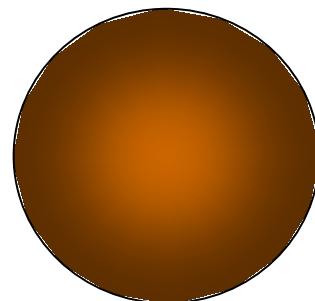
linking $m(^{28}\text{Si})$ to $m(\text{IPK})$

silicon-28 atom,
mass = $\textcolor{red}{m}(^{28}\text{Si})$



n

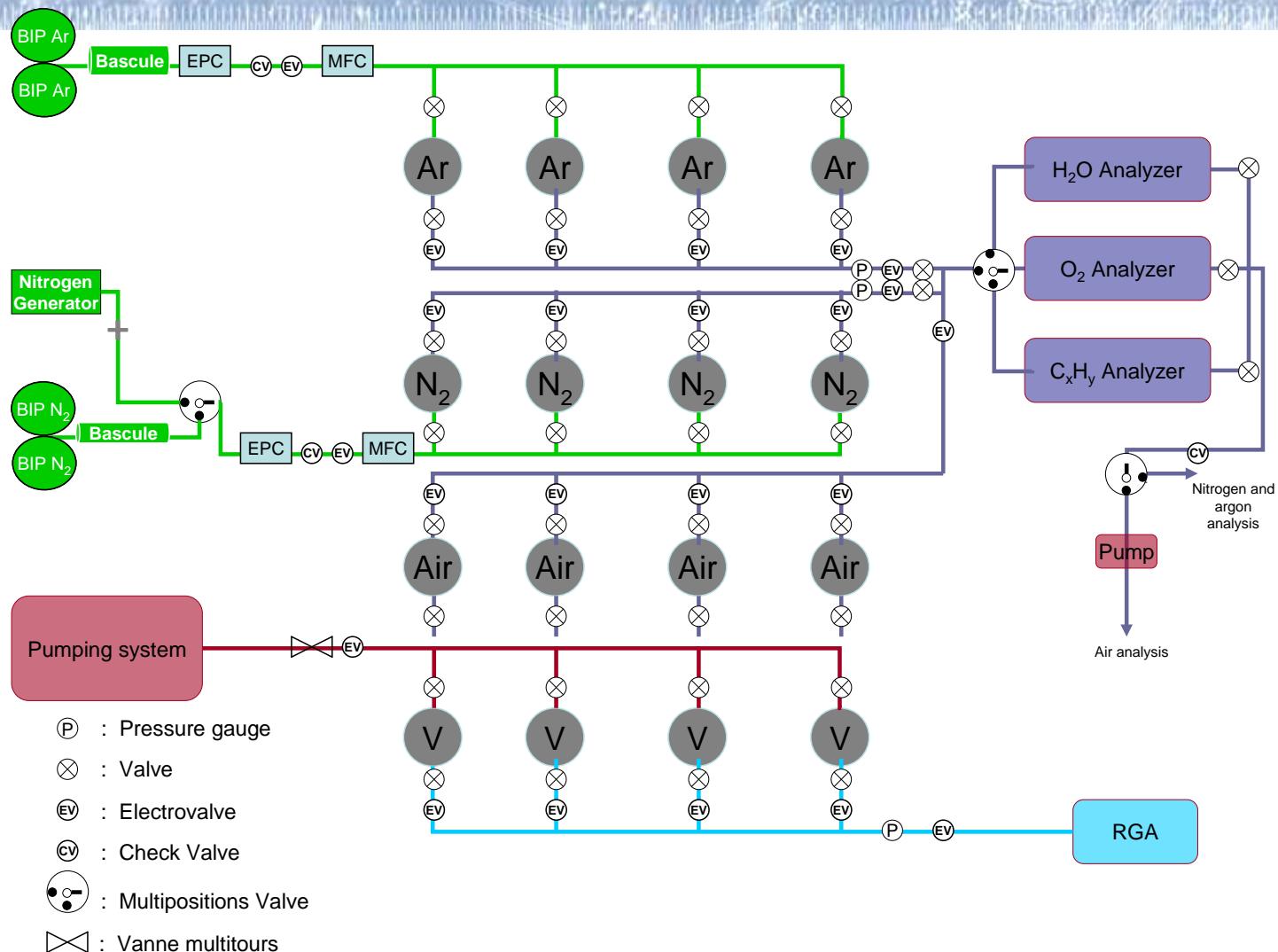
sphere
mass = $\textcolor{red}{m}$, traceable to $m(\text{IPK})$



n atoms
to make a
1 kg sphere
($n \gg 2 \cdot 10^{25} !$)

$$m(^{28}\text{Si}) = \frac{\text{constant}}{n} \cdot m_{\emptyset}$$

Storage network for the pool of artefacts



Future high-energy photon dosimetry at the BIPM

All Member States contributing to the BIPM operate LINACs for cancer treatment

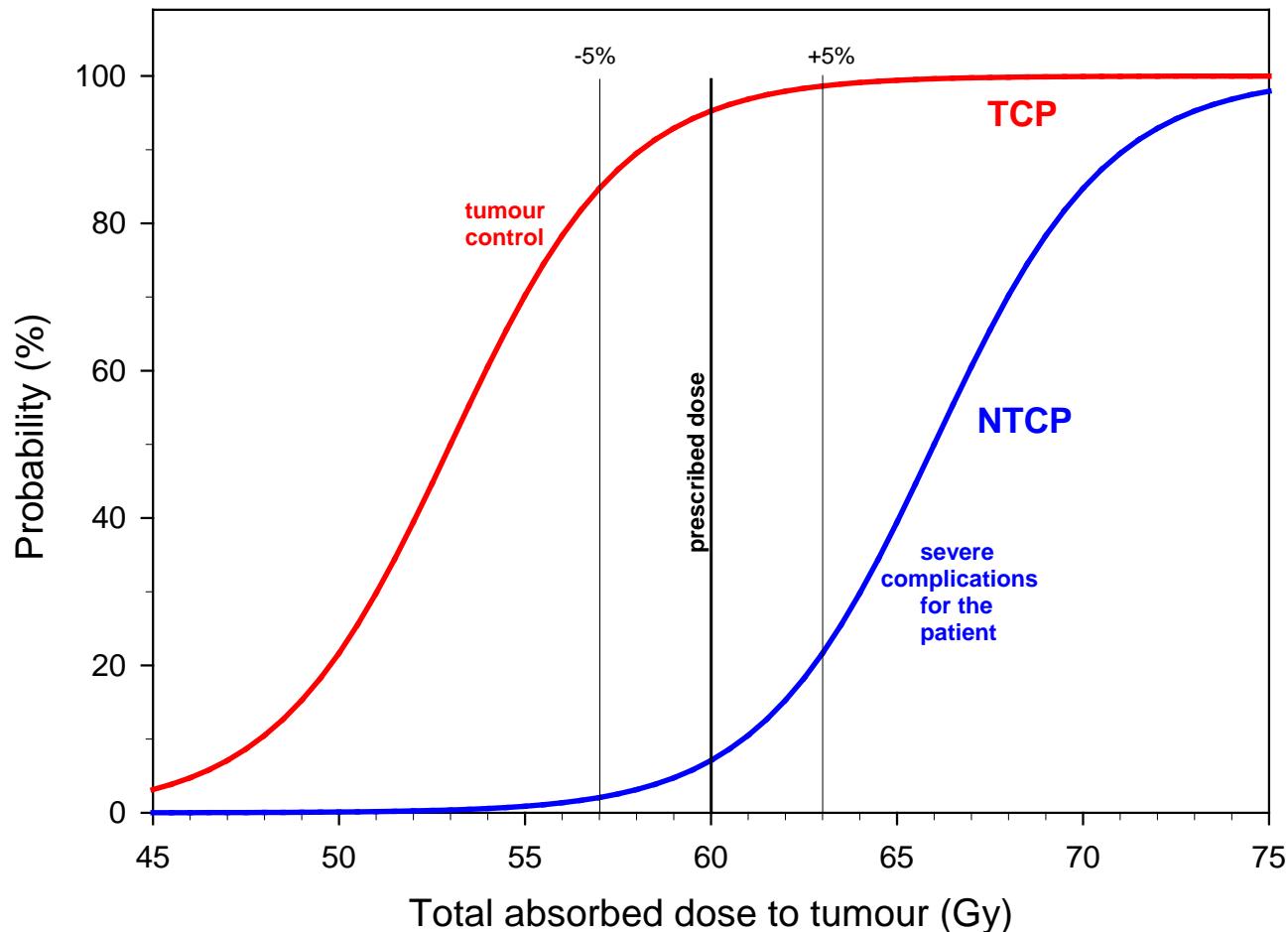
Use of a LINAC by the BIPM together with the graphite calorimeter would provide:

- ⊕ comparisons of primary standards for Member States particularly where their NMI operates a LINAC, to provide degrees of equivalence
- ⊕ calibrations of national standards for those Member States where their NMI does not operate a LINAC



Schematic representation : expected treatment outcome

dose delivered to the patient within 5 %



International support for high-energy photon dosimetry at the BIPM



Mr. Andrew J. Wallard	Director
Division of Technical Cooperation	Position de Reponsable
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Geneva, Switzerland	Telephone: +41 22 791 31 11
Telex: 61 111 WHO GENEVA	Fax: +41 22 791 31 65
E-mail: wallard@who.ch	Telex: 61 111 WHO GENEVA
24 September 2000	
<p>Dear Dr. Wallard,</p> <p>Having heard considerable of the suggestion of the members of the BIPM to extend the dosimetry standard to dosimetry photon and electron beams as are now used in clinical radiotherapy throughout the World, WHO would like to take the opportunity to welcome the request. It is important to note that the IAEA has already taken a lead role in this endeavour and the IAEA programme can partly harmonize IAEA and WHO.</p> <p>The IAEA World Network of Secondary Standard Dosimetry Laboratories (SSDL) network was established in 1976 as a joint project between IAEA and WHO. At present, it includes 90 laboratories and 9 SSDLs, national programmes in 87 Member States, which are still developing countries.</p> <p>The IAEA network also includes 27 affiliated institutions (Primary Standard Dosimetry Laboratories, PSDLs) and 7 collaborating organizations. Best apply support to the Network.</p> <p>The IAEA project has had responsibility to verify that the services provided by the national laboratories in the Member States are capable of meeting the needs of medical physics for traceability for radiation protection instruments. IAEA's support is accomplished first with the assistance of calibration facilities the members themselves. From the BIPM or PSDLs through the IAEA's Dosimetry Laboratory.</p> <p>For more than 20 years, the IAEA's dosimetry programme has operated a service to validate new dosimetry techniques in developing Member States using the IAEA/WHO SSDL portal dose quality audits. Originally the TLD (thermoluminescent dosimetry) service was designed for Co-60 therapy units, and since 1990 it provides audits of high-energy photon beams using the TLD technique. The TLD service also monitors facilities of TSDs in radiotherapy over 1990, and it has recently been extended to monitor radiation protection measurement in SSDLs.</p> <p style="text-align: right;">Yours faithfully,</p> <p>John P. Small, IAEA • IAEA/WHO</p> <p>Organisation mondiale de la Santé • Organización internacional de la Salud • Organización Mundial de la Salud</p>	

"For the SSDL network and the TLD programme, WHO is directly dependent upon the quality of work carried out by the BIPM. The suggestion to extend the facilities at the BIPM to include megavoltage dosimetry is thus emphatically supported."



"the IAEA could certainly facilitate the use of the future BIPM calibration services by its Member States through Technical Cooperation projects"



**International Commission on
Radiation Units & Measurements**



**International Commission on
Radiation Units and Measurements, Inc.**

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May 17, 2010

Professor Andrew J. Wallard, Director
Bureau International des Poids et Mesures
Bureau International du Breteil
F-92312 Sèvres Cedex
France

Dear Prof. Wallard:

The International Commission on Radiation Units and Measurements (ICRU) wishes to express its strong support for the acquisition by the Bureau International des Poids et Mesures (BIPM) of an electron-accelerator facility that will provide appropriate electron and high-energy x-ray beams to facilitate the comparison of national measurement standards for the dosimetry of these beams used in medical therapy. The ICRU has, since its inception in 1925, striven to develop and harmonize (a) quantities and units of ionizing radiation and radioactivity, (b) procedures for the measurement and application of these quantities in clinical radiology and radioisotopes, and (c) physical data needed in the application of these procedures to assure uniformity in reporting.

Early efforts of the ICRU focused on defining basic measurable quantities for the new x-ray beams finding increasing uses in medical applications. This work involved decades of numerous ICRU-hosted comparisons of instrument-based national measurement standards, leading to improved quantities, improved measurement, and convergence to an acceptable level of agreement and agreement on measurement standards. During the 1950s, the ICRU decided that the comparison of national standards could be better carried out by the BIPM as an integral part of its program under the Treaty of the Meter. The ICRU petition to the BIPM resulted in the establishment in 1958 of the Comité Consultatif pour les Étals de Mesure des Rayonnements Ionisants or the Consultative Committee on Standards for the Measurement of Ionizing Radiations (CCMRI), which was renamed the Consultative Committee on Ionizing Radiation (CCRI) in 1997.

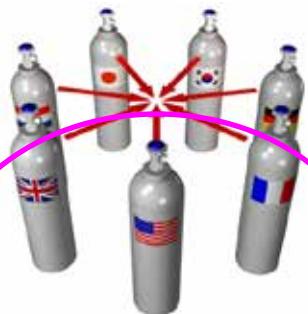
ICRU is a not-for-profit scientific organization

REÇU
Le 25 MAI 2010

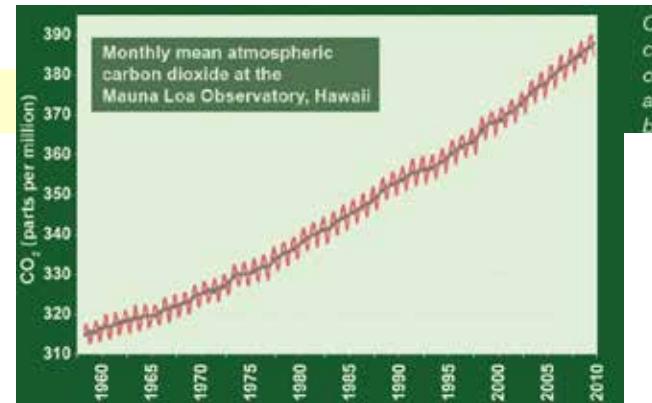
"The success over more than a half-century of the BIPM program in ionizing radiation has been outstanding, greatly facilitating the improvement and harmonization of measurements of ionizing radiation worldwide"

Responding to the Challenge of Greenhouse Gas Monitoring

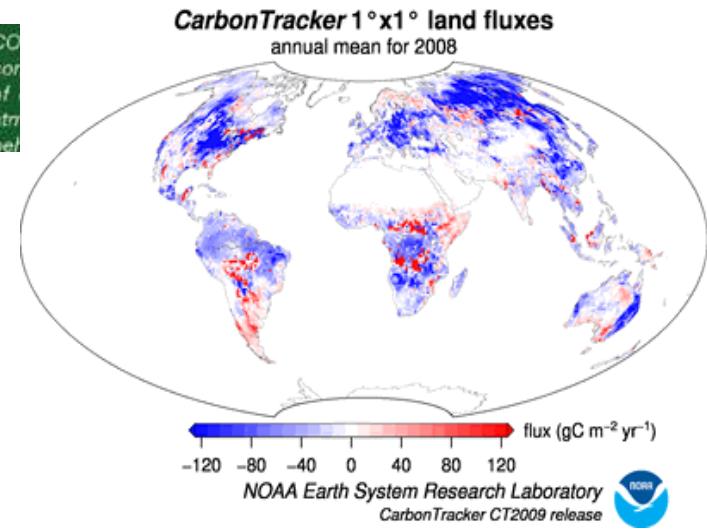
- ⊕ Climate Change: Mitigation and Cap and Trade Legislation on GHG emissions
- ⊕ Accurate data for informed policy decisions
- ⊕ Verification of national emission inventories through measurement
- ⊕ Major Observational network expansion
- ⊕ Stringent requirements on equivalence of GHG calibration standards
- ⊕ Degree of equivalence of GHG standards assured by BIPM coordinated comparisons



BIPM Key Comparisons



GHG monitoring stations/networks

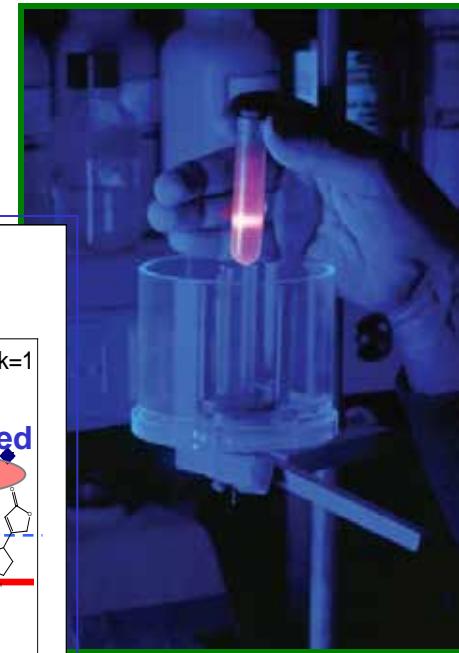


CO₂ Flux Maps – Emission Verification

Comparisons for Primary Calibrators for Laboratory Medicine, Pharma, Food Analysis and Forensics



Metrological traceability for organic analysis:
BIPM programme



BIPM - Bureau International des Poids et Mesures

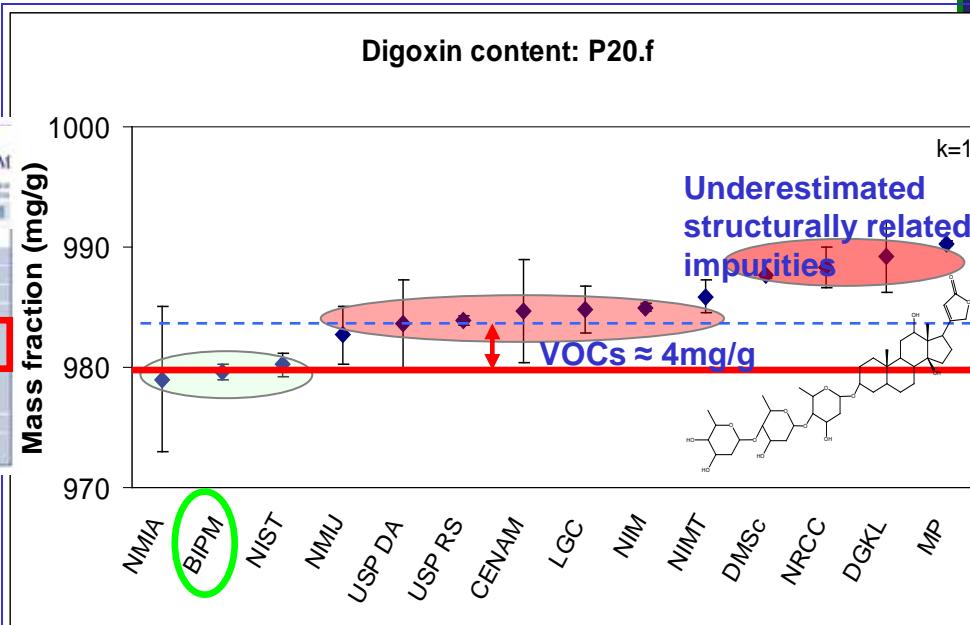
JCTLM - JCTLM Database: Laboratory medicine and in vitro diagnostics

Database of higher-order reference materials, measurement methods/procedures and services

If you are here: JCTLM > Reference measurement services > Lab

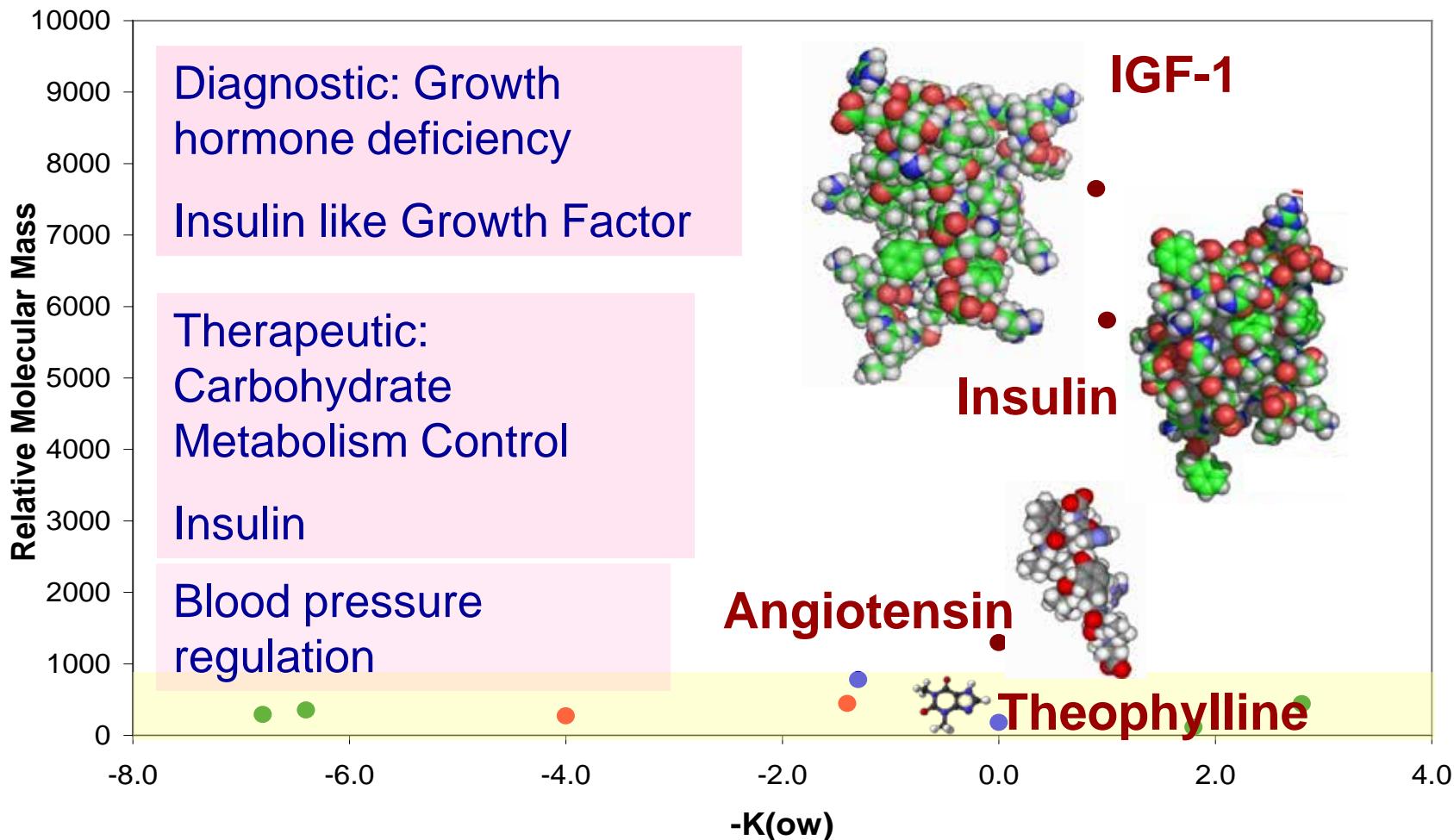
Web: <http://www.bipm.org/jctlm/>

Analyte	Digoxin
Material or matrix	Blood serum, blood plasma
Quantity	Around-of-subsidence concentrations
Service measurement range	0.1 ng/mL to 40 ng/mL
Expanded uncertainty (level of confidence 95%)	± 4.1 % w/ 2.2 % The given uncertainties do not relate to the lower and upper limits of determination
Interlaboratory comparison results	RELA - IFCC External Quality assessment scheme for Reference Laboratories in Laboratory Medicine at: http://www.bipm.org/jctlm/rela/
Measurement principle	Isotope dilution mass spectrometry (IDMS)
JCTLM reference measurement method/ procedure	DIGKC definitive method for serum digoxin



Metrology for Health: Improved Diagnostics and Therapeutics

Extension of Organic Primary Calibrator Comparisons



SI Metrology for diagnosing and treating Diabetes



- 220 million people worldwide have diabetes**
- 438 million people are expected to be affected by 2030[†]
- Diabetes affects 25.8 million people in the U.S.
(8.3% of the population)*
- \$ 174 billion – estimated diabetes costs in the U.S. in 2007 (direct and indirect)*
- 2.6 million people diagnosed with diabetes in the UK[†]
- £ 9 billion (10% of NHS budget) spent on diabetes per year in the UK[†]

**WHO: Diabetes fact sheet N° 312, January 2011

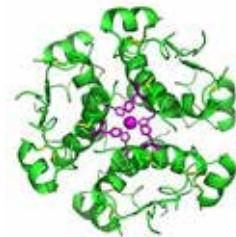
†Diabetes in the UK 2010 : key statistics on diabetes (Diabetes UK)

*Centers for Disease Control and Prevention. National diabetes fact sheet: national estimates and general information on diabetes and prediabetes in the United States, 2011. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2011.

IU to SI value assignment of Insulin Primary Standards

Primary Calibrator- Recombinant Human Insulin (rhINS)

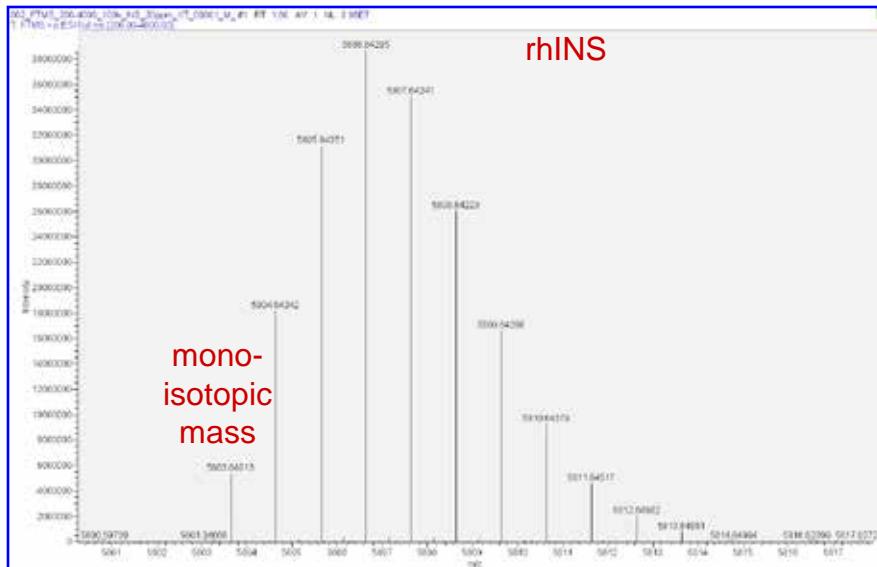
- A pancreas hormone, which plays a key role in the regulation of carbohydrates and fat metabolism in the body. A lack of insulin production/usage may lead to *Diabetes mellitus*.
- Small protein of two peptide chains (21+30 amino acids), MW of 5808 g/mol



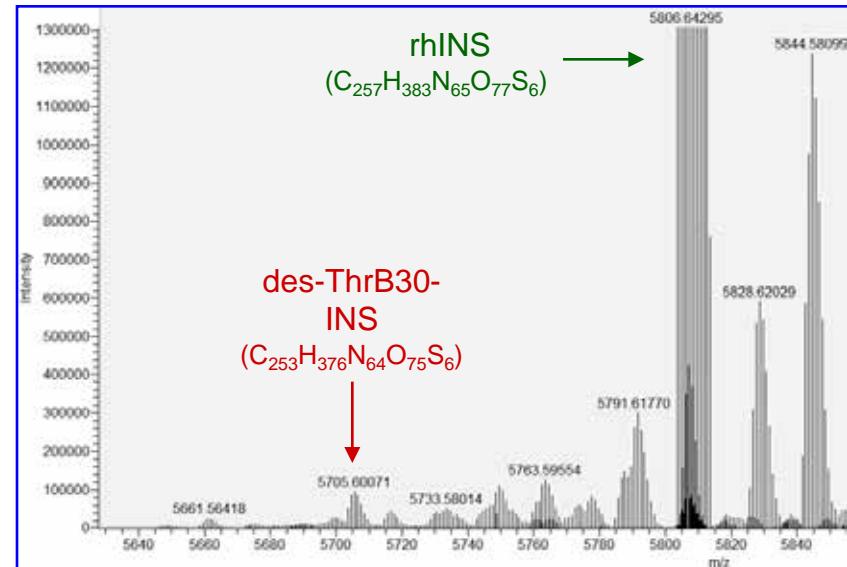
BIPM Project

- “Mass balance” purity value assignment study - determination of impurities of rhINS using multiple analytical techniques.
- LC-hrMS/MS is a powerful indispensable technique for the identification of structure related impurities of rhINS by accurate mass determination.

Zn complex of
3 rhINS-dimers



Deconvoluted infusion-MS spectrum: Isotope pattern of rhINS



Deconvoluted infusion-MS spectrum: rhINS and des-ThrB30-INS, an impurity which lacks the C-terminal amino acid Thr on the B chain of rhINS.

Aldosterone test kit performance

EQAS audit, samples testing with two kits, target value (middle of Youden diagram) by ID-MS

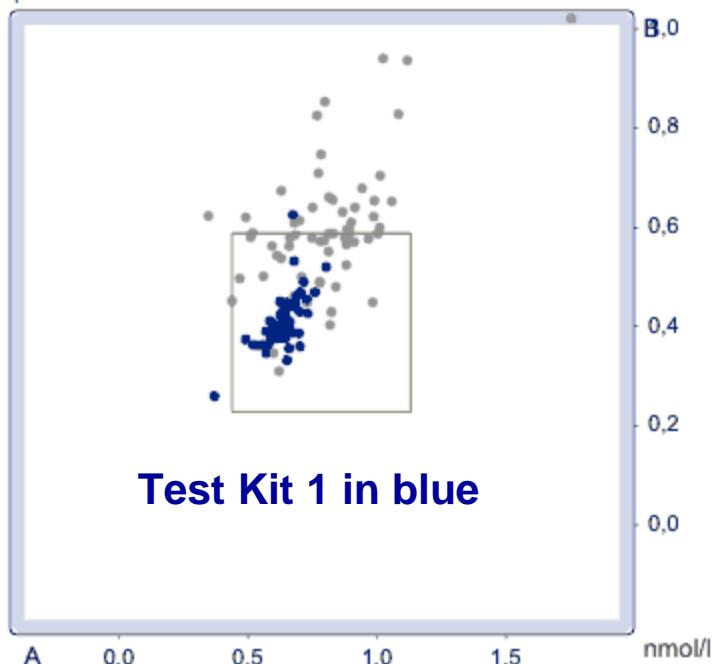
HM1/12

aldosterone

Radioaktivitätsmessung - Kit 44

Split 1

R f B



Test Kit 1 in blue

selected participants	64
target value	0.783
limits	0.438 - 1.13
mean value	0.637
standard deviation	0.063
coefficient of variation	9.905
0.408	
0.228 - 0.588	
0.411	
0.053	
13.016	

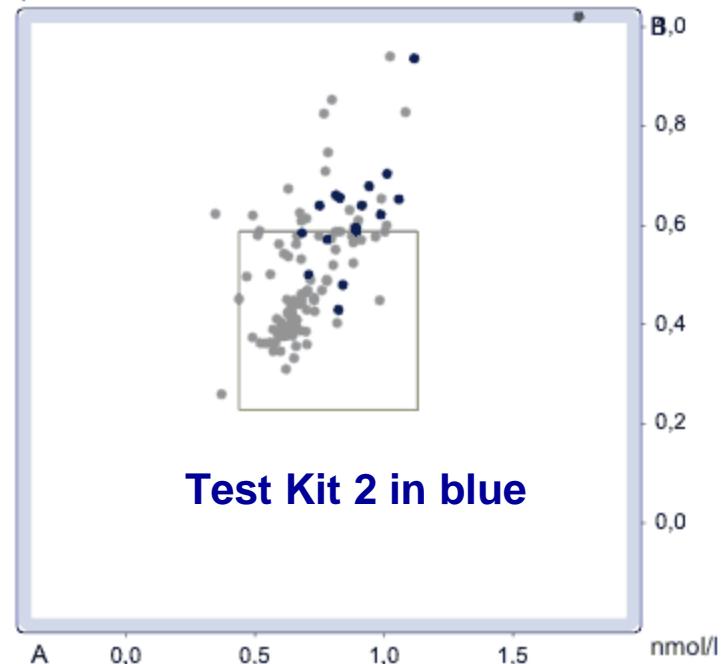
HM1/12

aldosterone

Radioaktivitätsmessung - Kit 111

Split 1

R f B



Test Kit 2 in blue

selected participants	17
target value	0.783
limits	0.438 - 1.13
mean value	0.929
standard deviation	0.244
coefficient of variation	26.266
0.408	
0.228 - 0.588	
0.674	
0.244	
36.202	

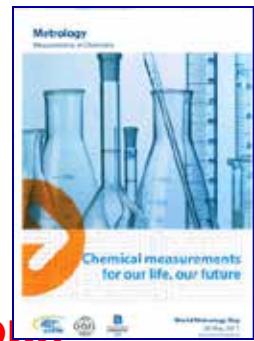
International Coordination and Liaison

Support of the Consultative Committees of the CIPM, including their Working Groups, by the provision of the Executive Secretaries.



Work with International Bodies (IBs, e.g., ISO and ILAC) and **Intergovernmental Organizations** (IGOs, e.g., OIML, IAEA).

Raise **public awareness of the BIPM and the CIPM MRA** through, for example, World Metrology Day activities.



Act as a central resource for the **planning and operation of workshops** to address new areas such as physiological quantities, nanotechnology, climate change (with the WMO), etc.



BIPM'S GLOBAL ROLE

Working with Governments, National Metrology Institutes, and the accreditation community so as to maintain confidence in the world measurement system for science and trade.

To address the common interest of the NMIs of States Parties to the Metre Convention in dealings with international and intergovernmental bodies such as the World Meteorological Organisation, World Health Organisation, the International Federation of Clinical Chemistry, International Laboratory Accreditation Co-operation, International Organisation for Legal Metrology etc. as the occasion arises.



Conclusion

THE ROLE OF THE BIPM IS WORLDWIDE UNIFORMITY OF MEASUREMENT.

It achieves this through providing the necessary scientific and technical basis for such uniformity and by collaborating with other institutions and organisations that have related missions.





Bureau International des Poids et Mesures

Thank you for your attention

