

# *Mise en pratique* of the (new) definition of the mole

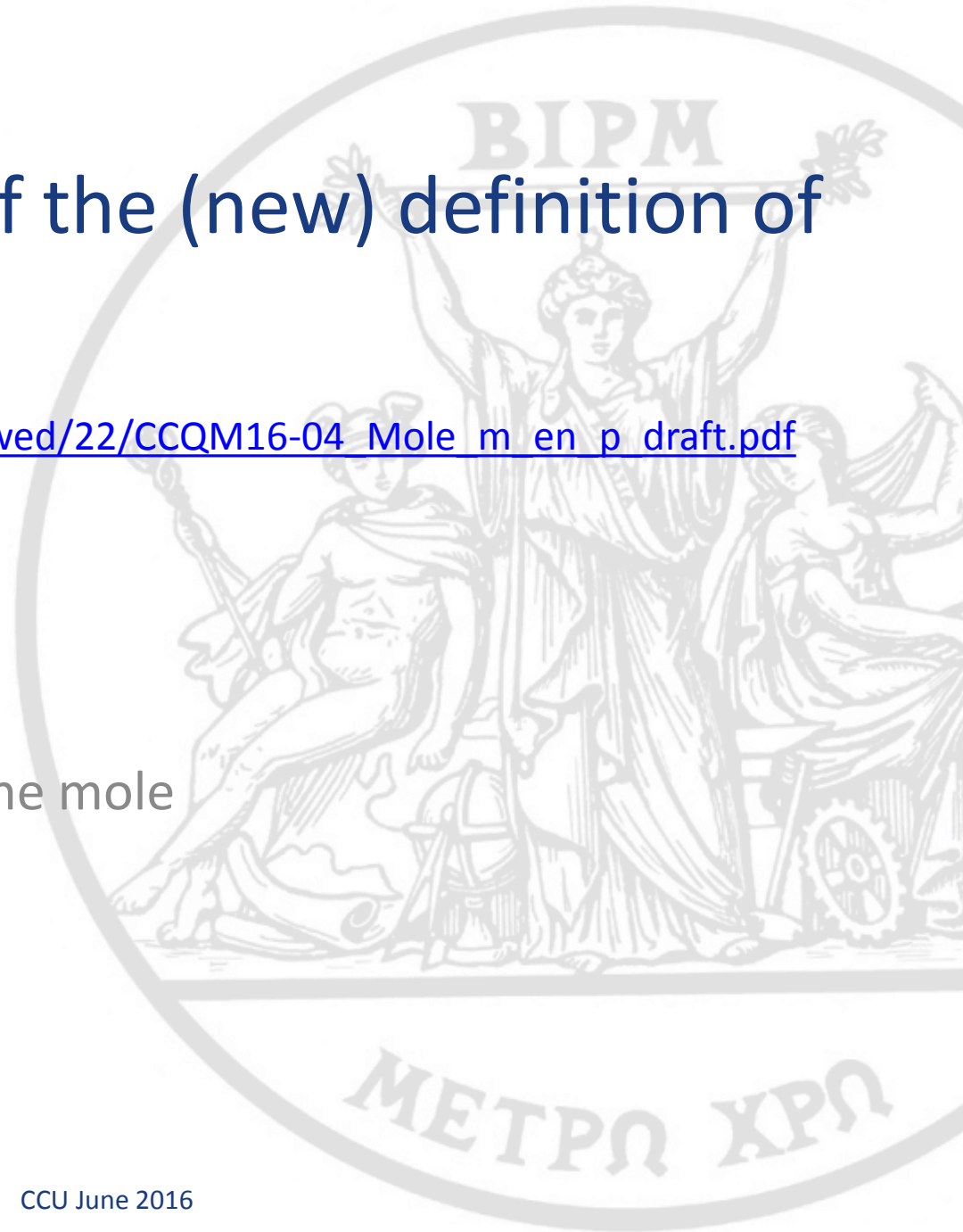
current draft:

[http://www.bipm.org/cc/CCQM/Allowed/22/CCQM16-04\\_Mole\\_m\\_en\\_p\\_draft.pdf](http://www.bipm.org/cc/CCQM/Allowed/22/CCQM16-04_Mole_m_en_p_draft.pdf)

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# Mission statement

The screenshot shows a web browser window with the URL [www.bipm.org/en/committees/cc/wg/mole.html](http://www.bipm.org/en/committees/cc/wg/mole.html). The page features the BIPM logo and tagline: "Bureau International des Poids et Mesures - the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards." A search facility is located in the top right corner. A navigation menu includes: ABOUT US, WORLDWIDE METROLOGY, INTERNATIONAL EQUIVALENCE, MEASUREMENT UNITS, SERVICES, PUBLICATIONS, MEETINGS. A breadcrumb trail reads: > You are here: worldwide metrology: committee structure > Consultative Committees > CCQM > MOLE. The main heading is "CCQM ad hoc Working Group on the Mole". Below this, there are two tabs: "Mission" (selected) and "CCQM". The "Mission" tab contains the following text: "→ **Chair:** Dr B. Güttler, PTB" and "→ **Remit:**" followed by a numbered list: "1. To draft a *\"mise-en-pratique\"* for the realization of the mole;" and "2. To create awareness with respect to a possible redefinition of the mole, explain reasons and prepare opinions for discussion in the CCQM." On the right side, there are two sidebars. The first is titled "CCQM summary" and lists: "General information", "CCQM members", "CCQM working groups", "CCQM pilot studies", "CCQM strategy", "CCQM workshops", "CCQM publications and forms", "Photographs of the CCQM", "Key comparisons" (with a KCDB icon), and "Summary of CCQM Key Comparisons and Pilot Studies". The second sidebar is titled "Open documents" and lists: "CCQM documents" and "GAWG documents". At the bottom of the page, a yellow bar contains the text "Metrology area:" followed by a series of letters: AUV, EM, L, M, PR, QM, RI, T, TF, U.

## *mise en pratique* (quick review)

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$$n(\mathbf{X}) = \frac{N(\mathbf{X})}{N_{\text{A}}}$$

amount of X

n° of X entities

Avogadro constant

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$$n(\mathbf{X}) = \frac{N(\mathbf{X})}{N_A}$$

n° of X entities

amount of X

Avogadro constant

$$N(^{28}\text{Si}) = \frac{8V_s}{a(^{28}\text{Si})^3}$$

Si XRCd  
(unique)

$$N(\mathbf{X}) = \frac{w(\mathbf{X})m}{m_a(\mathbf{X})}$$

gravimetry  
(most widely used)

$$N = \frac{pV}{kT}$$

gas analysis

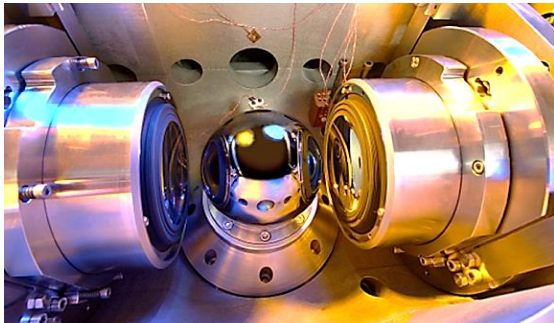
$$N = \frac{Q}{ze}$$

electrolysis

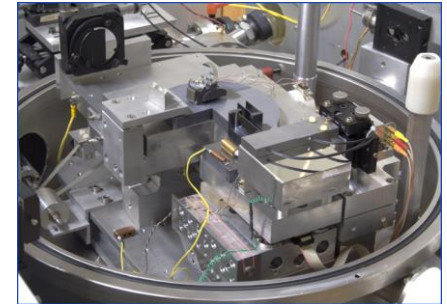
## 2. Realization of the definition of the mole with the smallest uncertainty

### ◆ Silicon XRCD

$$N(^{28}\text{Si}) = \frac{8V_S}{a(^{28}\text{Si})^3}$$



determine  $V_S$



determine  $a$

$$n = \frac{8V_S}{a(^{28}\text{Si})^3} N_A$$

$n$  equals volume,  $V_S$ , divided by molar volume,  $N_A a(^{28}\text{Si})^3/8$ .

$$u_r \sim 2 \times 10^{-8}$$

### 3. Common methods for the realization and dissemination of the mole

#### ◆ Gravimetric preparation



$$N(\mathbf{X}) = \frac{w(\mathbf{X})m}{m_a(\mathbf{X})} = \frac{w(\mathbf{X})m}{A_r(\mathbf{X})m_u}$$

$$n = \frac{w(\mathbf{X})m}{A_r(\mathbf{X})N_A m_u} = \frac{w(\mathbf{X})m}{A_r(\mathbf{X})M_u}$$

*n* equals total mass of X,  $w(\mathbf{X})m$ ,  
divided by molar mass of X,  $A_r(\mathbf{X})M_u$ .  
 $u_r > 10^{-6}$  is usual

### 3. Common methods for the realization and dissemination of the mole

- ◆ Use of the gas law



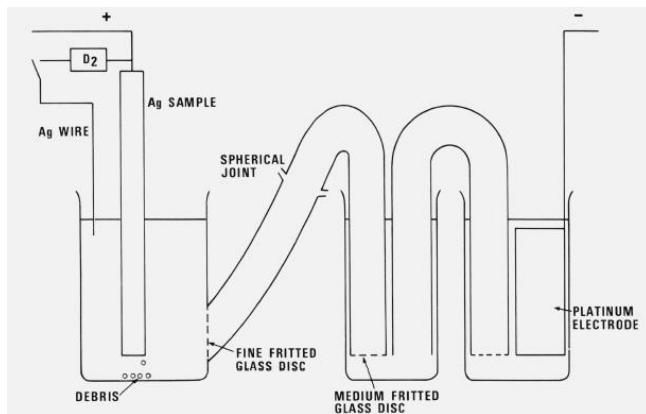
NOAA. relative mole fraction of CO<sub>2</sub> in air; 1997-present

$$pV = nRT \left[ 1 + B(T) \left( \frac{n}{V} \right) + \dots \right]$$

$R (=N_A k)$  has a fixed value

### 3. Common methods for the realization and dissemination of the mole

#### ◆ Electrolysis



Bower&Davis 1980; last electro-chemical measurement of  $F$

$$N = \frac{Q}{ze}$$

$$n = \frac{Q}{zN_A e} = \frac{Q}{zF}$$

$F (=N_A e)$  has a fixed value



## 5. Continuity with previous definition

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- ◆ The molar mass constant  $M_u$  no longer has a fixed value, but this has negligible consequences
- ◆ Recall slide 6:

$$n = \frac{w(\mathbf{X})m}{m_a(\mathbf{X})N_A} = \frac{w(\mathbf{X})m}{A_r(\mathbf{X})m_u N_A} = \frac{w(\mathbf{X})m}{A_r(\mathbf{X})M_u}$$

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- ◆ The *mise en pratique* shows the quantity relation

$$M_u = \frac{2N_A h}{c} \frac{R_\infty}{\alpha^2 A_r(\text{e})}$$

and states that  $M_u = 1.000\,000\,000 \cdot 10^{-3} \text{ kg mol}^{-1}$

with  $u_r < 10^{-9}$  (based on CODATA 2010; to be updated).

Next meeting of AHWG on the mole:  
TBD when needed.

(Next meeting of CCQM & WGs:  
April 2017.)