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CCQM Update

Richard Brown
on behalf of
Sang-Ryoul Park, CCQM President

Ad-hoc WG on the mole

National Physical Laboratory

- WG of the CCQM with the remit:
  - draft a "*mise en pratique*" for the realization of the mole
  - response to the CCU draft of the 9th SI Brochure
  - engagement with IUPAC activities
  - discuss and draft a new definition of the mole considering the opinions of the relevant stakeholders
  - create awareness of redefinition of the mole

- Membership: BIPM, INRIM, KRISS, NMIA, NIM, METAS, NIST, NMIJ, NPL, NRC, LGC, PTB
- 7 meetings and 2 workshops since 2010

Drafting the definition: Interaction with IUPAC

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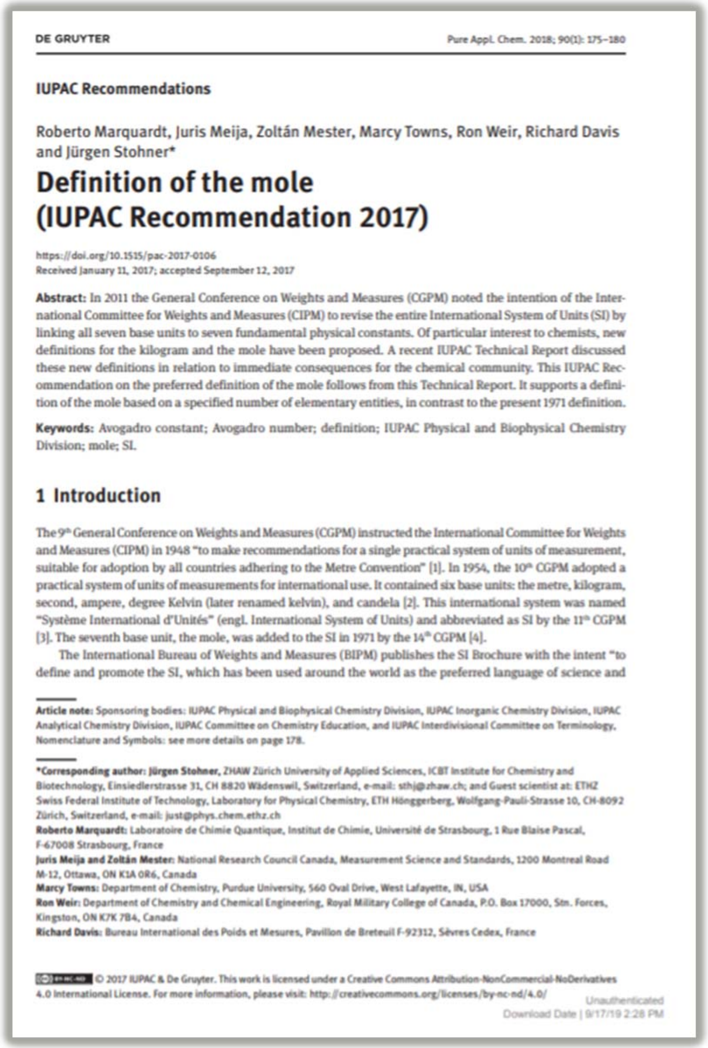
- Key stakeholder group – understanding of and teaching the mole
- Strong cooperation between CCQM & IUPAC – involvement in workshops
- IUPAC project on 'definition of the mole'
- Draft CCQM definition of the mole was modified according to IUPAC's comments
- Approved by the CCQM in April 2018
- Chemical community see explicit reference to N_A as a great improvement



DE GRUYTER

Pure Appl. Chem. 2018; 90(1): 175–180

IUPAC Recommendations

Roberto Marquardt, Juris Meija, Zoltán Mester, Marcy Towns, Ron Weir, Richard Davis and Jürgen Stohner*

Definition of the mole (IUPAC Recommendation 2017)

https://doi.org/10.1515/pac-2017-0106

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Abstract: In 2011 the General Conference on Weights and Measures (CGPM) noted the intention of the International Committee for Weights and Measures (CIPM) to revise the entire International System of Units (SI) by linking all seven base units to seven fundamental physical constants. Of particular interest to chemists, new definitions for the kilogram and the mole have been proposed. A recent IUPAC Technical Report discussed these new definitions in relation to immediate consequences for the chemical community. This IUPAC Recommendation on the preferred definition of the mole follows from this Technical Report. It supports a definition of the mole based on a specified number of elementary entities, in contrast to the present 1971 definition.

Keywords: Avogadro constant; Avogadro number; definition; IUPAC Physical and Biophysical Chemistry Division; mole; SI.

1 Introduction

The 9th General Conference on Weights and Measures (CGPM) instructed the International Committee for Weights and Measures (CIPM) in 1948 "to make recommendations for a single practical system of units of measurement, suitable for adoption by all countries adhering to the Metre Convention" [1]. In 1954, the 10th CGPM adopted a practical system of units of measurements for international use. It contained six base units: the metre, kilogram, second, ampere, degree Kelvin (later renamed kelvin), and candela [2]. This international system was named "Système International d'Unités" (engl. International System of Units) and abbreviated as SI by the 11th CGPM [3]. The seventh base unit, the mole, was added to the SI in 1971 by the 14th CGPM [4].

The International Bureau of Weights and Measures (BIPM) publishes the SI Brochure with the intent "to define and promote the SI, which has been used around the world as the preferred language of science and

Article note: Sponsoring bodies: IUPAC Physical and Biophysical Chemistry Division, IUPAC Inorganic Chemistry Division, IUPAC Analytical Chemistry Division, IUPAC Committee on Chemistry Education, and IUPAC Interdivisional Committee on Terminology, Nomenclature and Symbols: see more details on page 178.

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New definition

The mole

The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.022\,140\,76 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number.

The amount of substance, symbol *n*, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.

SI Brochure, 9th Edition, 2019

Mise-en-pratique

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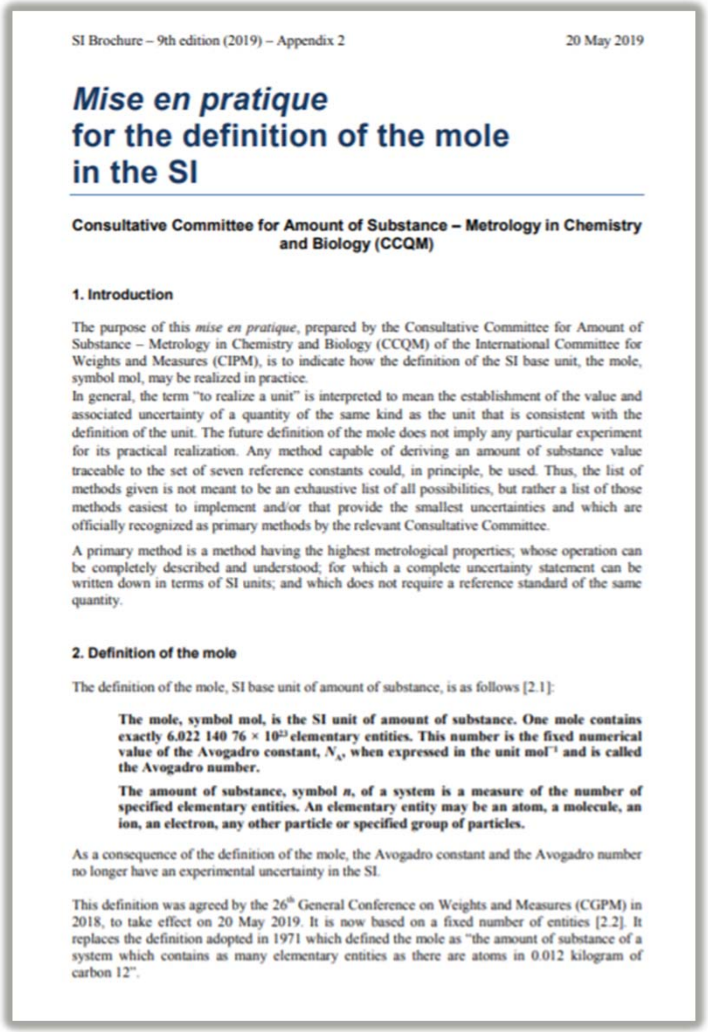
- Next task was to edit the *mise-en-pratique*, in particular:
  - incorporation of the Avogadro experiment
  - coordination with CCM: mise-en-pratique of the kg
  - continuity with the existing mise-en-pratique
  - small numbers of entities
  - continuity with previous defintion, u/c acquired by M_u
- Approved at the April 2019 CCQM meeting with minor comments dealt with at the start of May 2019



SI Brochure – 9th edition (2019) – Appendix 2 20 May 2019

Mise en pratique for the definition of the mole in the SI

Consultative Committee for Amount of Substance – Metrology in Chemistry and Biology (CCQM)

1. Introduction

The purpose of this *mise en pratique*, prepared by the Consultative Committee for Amount of Substance – Metrology in Chemistry and Biology (CCQM) of the International Committee for Weights and Measures (CIPM), is to indicate how the definition of the SI base unit, the mole, symbol mol, may be realized in practice.
In general, the term "to realize a unit" is interpreted to mean the establishment of the value and associated uncertainty of a quantity of the same kind as the unit that is consistent with the definition of the unit. The future definition of the mole does not imply any particular experiment for its practical realization. Any method capable of deriving an amount of substance value traceable to the set of seven reference constants could, in principle, be used. Thus, the list of methods given is not meant to be an exhaustive list of all possibilities, but rather a list of those methods easiest to implement and/or that provide the smallest uncertainties and which are officially recognized as primary methods by the relevant Consultative Committee.

A primary method is a method having the highest metrological properties; whose operation can be completely described and understood; for which a complete uncertainty statement can be written down in terms of SI units; and which does not require a reference standard of the same quantity.

2. Definition of the mole

The definition of the mole, SI base unit of amount of substance, is as follows [2.1]:

The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly 6.022 140 76 × 10^{23} elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number.

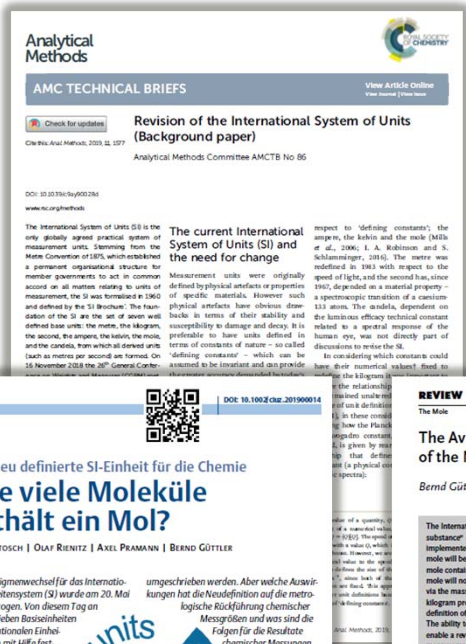
The amount of substance, symbol *n*, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.

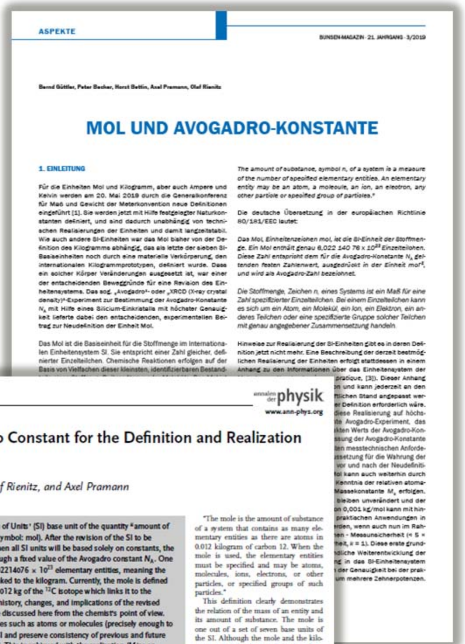
As a consequence of the definition of the mole, the Avogadro constant and the Avogadro number no longer have an experimental uncertainty in the SI.

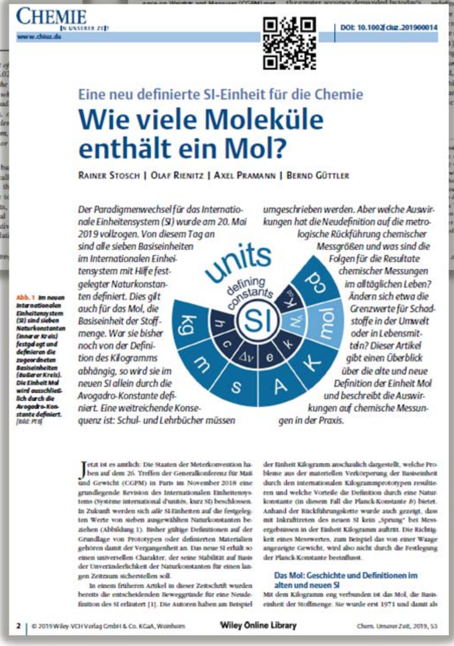
This definition was agreed by the 26th General Conference on Weights and Measures (CGPM) in 2018, to take effect on 20 May 2019. It is now based on a fixed number of entities [2.2]. It replaces the definition adopted in 1971 which defined the mole as "the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12".

Dissemination of the new definition

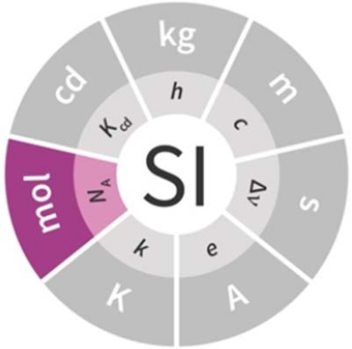

OPEN ACCESS IOP Publishing
Metrologia
Amount of substance and the mole in the SI
Bernd Güttler, Horst Bettin, Richard J C Brown, Richard S Davis, Zoltan Mester, Martin J T Milton, Axel Pramann, Olaf Rienitz, Robert D Vocke and Robert I Wielgosz

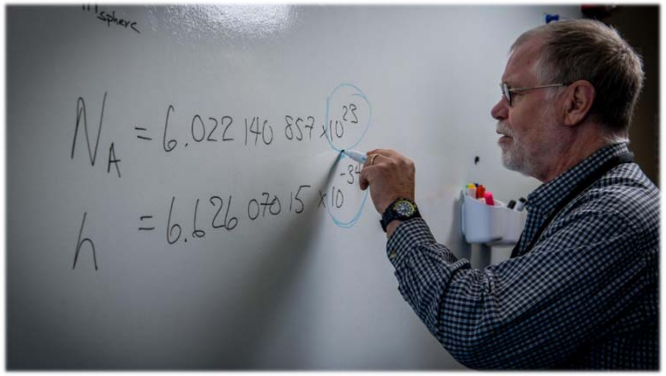

Analytical Methods
AMC TECHNICAL BRIEFS
Revision of the International System of Units (Background paper)
Analytical Methods Committee AMCTB No 86
The current International System of Units (SI) and the need for change


ASPEKTE
MOL UND AVOGADRO-KONSTANTE


CHEMIE in unserer Zeit
Eine neu definierte SI-Einheit für die Chemie
Wie viele Moleküle enthält ein Mol?
Rainer Stosch | Olaf Rienitz | Axel Pramann | Bernd Güttler


REVIEW
annalen der physik
The Avogadro Constant for the Definition and Realization of the Mole
Bernd Güttler, Olaf Rienitz, and Axel Pramann





Other CCQM activities

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- Traceability exceptions
  - One exception in the CIPM-MRA, for isotope ratio measurement
  - New IRWG established in CCQM, making progress with addressing these issues
- Method defined measurands
  - Defines requirements to be met for measurands to be eligible for CMC claims
  - Importantly, results expressed in SI units with metrologically valid methods are SI traceable

Bureau International des Poids et Mesures

TRACEABILITY EXCEPTION:

DELTA VALUE ISOTOPE RATIO MEASUREMENTS

Delta value isotope ratio measurements that cannot presently be made traceable to the SI should be made traceable to materials* recognised as International Standards. Since at present, values assigned to these materials are based on consensus values, these materials are not listed in the Appendix C of the BIPM Database.

> * A list of certified reference materials that should be used to identify accepted references for delta value isotope ratio traceability statements is published and maintained by IUPAC:
>
> Willi A. Brand, Tyler B. Coplen, Jochen Vogl, Martin Rosner and Thomas Prohaska
> Assessment of international reference materials for isotope-ratio analysis (IUPAC Technical Report)
> *Pure Appl. Chem.* 2014, **86**(3), 425-467
>
> The report is available for free download:
> http://www.degruyter.com/doi/10.1515/pac-2013-1023

The CIPM notes that assigned values for replacement materials should be done through a formal internationally vetted procedure that assures the continued comparability of delta value measurements.

The CIPM encourages the continuation of programmes within the NMIs to develop absolute isotope ratio measurement values for such Reference Materials and active engagement with the IUPAC community.

Traceability exception approved by the CIPM in March 2015
See Decision CIPM/104-26