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CHEMISTRY AND HUMAN HEALTH DIVISION
COMMISSION ON NOMENCLATURE, PROPERTIES, AND UNITS*

UNIT "KATAL" FOR CATALYTIC ACTIVITY

(IUPAC Technical Report)

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Unit "katal" for catalytic activity

(IUPAC Technical Report)

Abstract: Expressing the amount of a catalyst is often most conveniently done by assessing its catalytic effect. Under zero-order kinetics the catalyzed rate of conversion for a specified reaction is constant and proportionate to the amount-of-substance concentration of catalyst present. Defining the kind-of-quantity "catalytic activity" as a property of the catalyst measured by the catalyzed rate of conversion, the coherent SI unit is mole per second. Following thorough discussions in the IUPAC, the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), the International Union of Biochemistry and Molecular Biology (IUBMB), and the World Health Organization (WHO), a petition was presented by the IFCC to the International Committee for Weights and Measures (CIPM) on a special name "katal", symbol kat, for "mole per second" when used in measuring catalytic activity. This request was granted by the General Conference for Weights and Measures (CGPM) by Resolution 12 (1999). Hereafter, the coherent SI unit katal = 1 mol · s^{-1} should replace the off-system IUB unit "(enzyme) unit" = 1 μmol · min^{-1} ≈ 16.67 nkat. Thus, by suitable definition of reaction conditions, results for catalytic activity and derivative kinds-of-quantity are metrologically traceable to the SI.

INTRODUCTION

The amount of a catalyst in principle may be expressed as a number of elementary entities, an amount of substance, a mass, or by a catalytic effect. In some cases, due to lack of information or for practical reasons, the latter way is chosen.

Then, a suitable chemical reaction is catalyzed under optimized conditions, preferably so that zero-order kinetics is achieved by a much higher amount-of-substance concentration of substrate than of catalyst, giving a constant rate of conversion proportional to the amount-of-substance concentration of catalyst in the reaction mixture.

KIND-OF-QUANTITY

The kind-of-quantity to assess is "catalytic activity" defined as a "property of a catalytic component measured by its catalyzed rate of conversion of a specified chemical reaction in a specified measurement system", $\dot{\xi}_{B,\,cat} = d\xi_{B,\,cat}/dt \approx (\Delta n_{B,\,cat}/\nu)/\Delta t)$ [1].

PROPOSED UNITS

As a unit for this kind-of-quantity, the International Union of Biochemistry (IUB), in 1961 recommended the "unit (of enzyme)", U = 1 μmol/min [2]—off-system to SI.

Preferring coherent SI units, the IUPAC Commission on Clinical Chemistry jointly with the International Federation of Clinical Chemistry (IFCC) made a Recommendation 1966 to express catalytic amount in a base unit "catal" (cat) $\hat{=}$ 1 mol/s [3]. Around 1975, IUPAC, IFCC, IUB, and the World Health Organization (WHO) came to agree on the terms so that the derived kind-of-quantity catalytic activity, z, should be expressed in the coherent unit "katal", kat = 1 mol/s [4–7].

In 1978, the IFCC through IUPAC made a proposal to the Consultative Committee for Units (CCU) of the International Committee for Weights and Measures (CIPM) to adopt the katal as a special name for mole per second when expressing catalytic activity, but the proposal was not pursued [8].

The use of the katal, especially for measuring enzyme concentrations in laboratory medicine, has been spotty in spite of the recurrent appearance of recommendations, including the 1995 IUPAC/IFCC *Compendium of Terminology and Nomenclature of Properties in Clinical Laboratory Sciences*, "the Silver Book" [9]. Two reasons have been the inertia induced by habit and the lack of recognition by the General Conference for Weights and Measures (CGPM).

With respect to the latter obstacle, the IFCC Committee on Nomenclature, Properties, and Units—supported by the IUPAC Commission VII.1 of the same name—drafted a formal petition which IFCC submitted to the CIPM in 1998: "The special name 'katal' for the SI coherent derived unit of measurement 'mole per second' when used in expressing 'catalytic activity'".

The CIPM consulted the CCU in 1998 [10] and the Consultative Committee for Amount of Substance (CCQM) in 1999 [11]; they both supported the petition [12,13].

CGPM RESOLUTION

As an outcome, the 21st CGPM 1999 issued Resolution 12 deciding "to adopt the special name katal, symbol kat, for the SI unit mole per second to express catalytic activity, especially in the fields of medicine and biochemistry" and recommending "that when the katal is used, the measurand be specified by reference to the measurement procedure; the measurement procedure must identify the indicator reaction" [14].

It should be stressed that the katal is used in expressing kinds-of-quantity of the original system containing the catalyst, whereas the rate of conversion is a kind-of-quantity of the chemical reaction in the measuring system and—in spite of equidimensionality—should be expressed in mole per second, not katal.

THE INTERNATIONAL SYSTEM OF UNITS (SI)

The kind-of-quantity term, catalytic activity, and the unit term, katal, and symbol, kat, now appear in Table 3 of *The International System of Units, Supplement 2000* by the International Bureau of Weights and Measures [14] and, presumably, will also be entered in ISO 31 tables, joining such units as hertz, newton, volt, and becquerel.

Naturally, the special term can also be used in pharmacy (as is currently the case [15]) and in other fields where catalysts are measured by their catalytic effect, such as those covered by IUPAC Commission I.6 on Colloid and Surface Chemistry including Catalysts.

KINDS-OF-QUANTITY DERIVED FROM "CATALYTIC ACTIVITY"

Derivatives of catalytic activity lead to the following pairs of kind-of-quantity and coherent SI unit.

- catalytic activity, z
  katal, kat = mol/s (1 U = 1 μmol/min ≈ 16.67 nkat)
- catalytic-activity concentration, $b = z/V_s$
  katal per cubic meter, kat/m^3
- catalytic-activity content, z/m_s
  katal per kilogram, kat/kg
- entitic catalytic-activity, z/N
  katal, kat
- molar catalytic-activity, z_m
  katal per mole, kat/mol

- catalytic-activity rate, $\dot{z} = \mathrm{d}z/\mathrm{d}t$
  katal per second, kat/s
- catalytic-activity concentration rate, $\mathrm{d}b/\mathrm{d}t$
  katal per cubic metre second
- catalytic-activity content rate, $\mathrm{d}(z/m)/\mathrm{d}t$
  katal per kilogram second
- catalytic-activity fraction, z_f
  one or katal per katal, 1 or kat/kat

CONCLUSION

Thus, when a measuring catalytic reaction is sufficiently well known, it is now possible to express values for the various types of amount, concentration, etc. of inorganic or organic catalysts in the original sampled system in a convenient manner with metrological traceability to the SI. It is therefore hoped that the katal—after long and tortuous development (as detailed in ref. 16)—will supplant current off-system units of catalytic actitivity. Already the katal appears as the stipulated unit for all properties having enzyme components as listed in the IUPAC/IFCC series on "Properties and units in the clinical laboratory sciences" [17] issued by the IUPAC Commission on Nomenclature, Properties, and Units and the IFCC Committee of the same name.

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