# The Silver Book and the NPU Format for Clinical Laboratory Science Reports Regarding Properties, Units, and Symbols

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Standardized terminology was presented by IUPAC and by IFCC in 1967 [1] and is now updated by the second edition of the Silver Book 2017 [2] which gives recommendations for the clinical laboratory requests and reports, thus ensuring clear meaning and accuracy. The Nomenclature for Properties and Units (NPU) adheres to international standards of metrology and of terminology, in particular the International System of Quantities (ISQ) and International System of Units (SI) [3], the International vocabulary of metrology – basic and general concepts and associated terms (VIM) [4], and also to an outline for a vocabulary of nominal properties and examinations [5]. The NPU format applies to multiple disciplines, including clinical allergology, clinical chemistry, clinical haematology, clinical immunology and blood banking, clinical microbiology, clinical pharmacology, molecular biology and genetics, reproduction and fertility, thrombosis and haemostasis, and toxicology [2]. The present Leaflet recalls the definitions of the concepts used to express a property of a person. The aim of this comprehensive summary is to promote the proper NPU terminology for reliable exchange of person examination data, thus improving person information, comparative and epidemiological studies, and interoperability in the eHealth domain [6].

## Basic Concepts in the NPU Format

The terminography used in the examples below adheres to the NPU format, where each of the three main elements of a property term may be augmented by an immediately following parenthetic specification:

System(specification)—Component(specification); kind-of-property(specification)
= nominal property value, ordinal quantity value, or quantity value and unit as appropriate

**system**: part or phenomenon of the perceivable or conceivable world consisting of a demarcated arrangement of a set of components and a set of relations or processes between these components [modified from 7]. In human biology, it may be a person or a body part of a person or the immediate surroundings; *e.g.* Person, Blood, Urine, Kidney, Beta cells of the pancreas, Exhaled air. The initial letter of the term for a system is a capital letter. The term (and any specification) is followed by a long dash.

**component**: part of a system [7]. The component may be a physical part of the system, a chemical or biochemical compound, or a process; *e.g.* Calculus, Glucose, Intestinal absorption, Cortisol secretion. The initial letter of the term for a component is a capital letter. The term (and any specification) is followed by a semicolon.

**kind-of-property**: common defining aspect of mutually comparable properties [7]. The term of this concept is hyphenated to emphasize that it is a single term. Examples are number concentration ($C$), volume ($V$), amount-of-substance ($n$), substance concentration ($c$), catalytic-activity concentration ($b_{\mathrm{E}}$), taxon, sequence variation. The initial letter of the term is lower case.

**dedicated kind-of-property**: kind-of-property with given sort of system and any pertinent sorts of component [7]; *e.g.*
Patient—; mass
Patient—Glucose; substance concentration(procedure).

**property**: state- or process-descriptive feature of a system including any pertinent components [modified from 7]; *e.g.* Patient(Urine)—Glucose; substance rate(procedure) = 8 $\mathrm{mmol{\cdot}d^{-1}}$ . The modifier “procedure” refers to the examination procedure. As the set of possible values will depend on the local procedure, this procedure should be indicated in the report, *e.g.* Plasma—Lactate dehydrogenase; catalytic-activity concentration(IFCC 2002) = 3.2 $\mathrm{\mu kat{\cdot}L^{-1}}$ .

First efforts at the standardization of data transmission in clinical laboratories concerned quantities, *i.e.* those properties that have a magnitude, mostly expressed by a number and a unit [1]. However, many important properties of a classificatory nature such as species of microbes or genetic structure are inherently devoid of magnitude. In such cases, the superordinate concept 'property' can be generically divided in four types of property according to algebraic characteristics [7]:

- **nominal property**: property, defined by an examination procedure, that can be compared for equivalence with another property of the same kind-of-property, but has no magnitude [modified from 7] ; *e.g.* Urine—Neuroleptic drug; taxon(procedure) = chlorpromazine.

**- ordinal property, ordinal quantity**: property, defined by an examination procedure, having a magnitude and that can be stated only to be lesser than, equal to, or greater than another property of the same kind-of-property [7]; *e.g.* Urine—Bilirubins; arbitrary concentration({0, 1, 2, 4}; procedure) = 2.

**- differential property, differential quantity**: property having a magnitude and that can be subtracted from, but cannot be divided by another property of the same kind-of-property [7]; *e.g.* Patient—Rectum; Celsius temperature = 36.5 °C. **Logarithmic differential property** is used when the measurement scale consists of logarithmic values; *e.g.* Urine—; pH = 6.1.

**- rational property, rational quantity**: property having a magnitude and that can be divided by another property of the same kind-of-property [7]; *e.g.* Blood—Erythrocytes; volume fraction = 0.41 or as per cent 41 %.

**quantity**: property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed by a number and a reference [4]. A reference may be a measurement unit, a measurement procedure, a reference material, or a combination of such.

**kind-of-quantity**: aspect common to mutually comparable quantities [4, but without hyphens in the term]. Each kind-of-quantity may be designated by a term or a symbol, *e.g.* length ($l$), and mass concentration ($\rho$). A given kind-of-quantity may have synonyms; *e.g.* relative molecular mass and molecular weight (deprecated by the ISO [8]), and also synonymous symbols; *e.g.* $A$ and $S$ for area. A given symbol is sometimes used for different kinds-of-quantity; *e.g.* $A$ is the recognized symbol for area, nucleon number, Helmholtz energy, affinity of chemical reaction, and absorbance. The concepts here termed "kinds-of-quantity" are generally termed "quantity" by CGPM [3] and ISO/IEC 80000-1 [8].

**quantity of dimension one**, also termed dimensionless quantity: quantity for which all the exponents of the factors corresponding to the base quantities in its quantity dimension are zero [4]: $\mathsf{L}^0\mathsf{M}^0\mathsf{T}^0\mathsf{I}^0\Theta^0\mathsf{N}^0\mathsf{J}^0 = 1$. Quantities of dimension one may be divided according to their kinds-of-quantity into fractions, ratios, and relative kinds-of-quantity:

**- fraction**: quotient of two identical kinds-of-quantity, for which the numerator kind-of-quantity relates to a component B and the denominator kind-of-quantity relates to the given system; *e.g.* Erythrocytes(Blood)—Reticulocytes; number fraction $= 6 \times 10^{-3}$ or 0.6 % or 6 ‰. ISO/IEC 80000-1 accepts per cent with the symbol % for the submultiple unit 0.01, and per mille with the symbol ‰ for the submultiple unit 0.001 [8].

**- ratio**: quotient of two identical kinds-of-quantity, for which the numerator kind-of-quantity relates to a component B and the denominator kind-of-quantity to another component of the same system, commonly treated as a reference component; *e.g.* Sweat(specification)—Sodium ion/Potassium ion; substance ratio = 3.80 or as 380 %.

**- relative kind-of-quantity**: quotient of two identical kinds-of-quantity, commonly two kinds-of-quantity related to different systems, the second being a reference system; *e.g.* Plasma—Coagulation factor XI; relative substance concentration(immunological; actual/norm; procedure) = 0.80 or as 80 %.

**arbitrary kind-of-quantity**: kind-of-quantity outside the ISQ. There is no dimension or SI unit involved; *e.g.* Thrombocytes(Blood)—Aggregation, collagen-induced; arbitrary activity({normal, lightly weakened, weakened, utmost weakened}; procedure) = lightly weakened. This example is also an ordinal quantity [2].

## Generalities Concerning Kinds-of-Quantity and Units

'Kinds-of-quantity' are used to classify quantities of the same kind. Quantities of the same kind within a given system of quantities have the same dimension. Different kinds-of-quantity can also have the same dimension; *e.g.* substance content ($n_B/m_{system}$) and molality ($n_B/m_{solvent}$) both have the dimension $\mathsf{NM}^{-1}$ and the coherent SI unit mol kg$^{-1}$.

### Base Kinds-of-Quantity in the ISQ, their Dimensions, and their Units in the SI

A base kind-of-quantity is one that is conventionally accepted as being independent of other base kinds-of-quantity in a system of kinds-of-quantity. The remaining kinds-of-quantity are derived and are related to base or derived units. To each base kind-of-quantity of the ISQ is assigned a dimension represented by a sans-serif capital-letter symbol (except for number of entities). For example, the dimension of amount-of-substance is represented by N.

| Base kind-of-quantity | | Base unit | | Dimension |
|---|---|---|---|---|
| Term | Symbol | Term | Symbol | Symbol |
| number (of entities) | $N$ | one | 1 | 1 |
| length | $l$ | metre | m | L |
| mass | $m$ | kilogram | kg | M |
| time | $t$ | second | s | T |
| electrical current | $I$ | ampere | A | I |
| thermodynamic temperature | $T$ | kelvin | K | Θ |
| amount-of-substance | $n$ | mole | mol | N |
| luminous intensity | $I_v$ | candela | cd | J |

Number of entities can be regarded as a base kind-of-quantity [ref. 4, § 1.4 note 3; ref. 8, part 1, § 3.4 note 3] and the number one (symbol 1) as a base unit [ref. 4, § 1.10 note 3].

The kind-of-quantity amount-of-substance is proportional to the number of specified entities that may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles [3]; *e.g.* Urine—Nitrogen(N); amount-of-substance(procedure) = 360 mmol.
The relationship is governed by the Avogadro constant (symbol $N_A$ or $L$): $n_B = N_B/N_A = N_B/L$.

## Symbols of Derived Kinds-of-Quantity, Coherent Derived SI Units, and Quantity Dimensions

Striving for monosemy, *i.e.* one symbol only relates to one concept, single-letters are sometimes modified by subscripts, superscripts, or different fonts, *e.g.* $A_r$ is the symbol for relative atomic mass (atomic weight), and $A_m$ is that for molar radioactivity. N is the dimensional symbol of amount-of-substance and N is the symbol of the unit newton. The unit for Celsius temperature, *i.e.* the degree Celsius (symbol °C), is equal in magnitude to the kelvin (symbol K), the unit of thermodynamic temperature. A Celsius temperature is given, *e.g.* as 37 °C (not 37, not 37° C, not 37°C, and not 37C).

The term "katal" and symbol "kat" for the 'SI coherent derived unit for catalytic activity' have been recognized by IUPAC, IFCC, International Union of Biochemistry and Molecular Biology (IUBMB), World Health Organization (WHO), and General Conference on Weights and Measures (CGPM) [3]. IUPAC & IFCC [9] recommended that the enzyme unit, international unit U be progressively replaced by submultiples of the katal, where 1 U = 1 $\mu mol \cdot min^{-1} \approx 16.67$ nkat; *e.g.* Plasma—Aspartate transaminase; catalytic-activity concentration(IFCC 2002) = $2.2 \times 10^{-6}$ $kat \cdot L^{-1}$ or 2.2 $\mu kat\ L^{-1}$.

A specification regarding the measurement procedure used is necessary when catalytic activity is involved, here "IFCC 2002". If the symbol U is used, it must not be confused with the symbol IU (meaning International Unit, also abbreviated int.unit), which is the symbol used by the WHO and mentioned in the SI Brochure [3] in expressing biological activity of certain substances that cannot yet be defined in terms of the SI; *e.g.* Plasma—Insulin; arbitrary substance concentration(IRP 66/304; procedure) = $120 \times 10^{-3}$ $IU \cdot L^{-1}$ , where IRP stands for International reference preparation of the WHO.

## Non-SI Units

Several non-SI units are widely used in clinical laboratory sciences and have corresponding values in SI units.

| Kind-of-quantity | Term for unit | Symbol for unit | Expression in terms of SI coherent unit |
|---|---|---|---|
| length | ångström | Å | $= 0.1 \times 10^{-9}$ m |
| volume | litre* | L, l | $= 10^{-3}$ $m^3$ |
| mass | dalton* | Da | $= 1.660\ 538\ 921(73) \times 10^{-27}$ kg |
| time | minute* | min | = 60 s |
| | hour* | h | = 3 600 s |
| | day* | d | $= 86.4 \times 10^3$ s |
| | week | wk | $= 604.8 \times 10^3$ s |
| | year | a | $\approx 31.556\ 952 \times 10^6$ s |
| pressure | millimetre of water | $mmH_2O$ | = 9.806 65 Pa |
| | millimetre of mercury | mmHg | ≈ 133.322 Pa |
| | bar | bar | $= 10^5$ Pa |

*Non-SI unit accepted by CGPM for use with the International System of Units [3]. The unmarked entries of the second column and their corresponding symbols have no official sanction from CGPM [3].

The symbol for litre is either L or l. ISO and IEC prefer l, because the term "litre" is not derived from the proper name of a person. L is preferred here to avoid confusion with the numeral 1 [2, 3]. Dalton is also termed unified atomic mass unit (symbol u); its standard uncertainty is indicated in the table parentheses.

## Prefixes for Multiples and Submultiples of Units

Prefixes denoting decimal factors $10^n$ have been defined [3]. For convenience, the Commission on Clinical Chemistry of IUPAC and IFCC recommended a preference in the clinical laboratory for decimal factors with decimal prefixes in steps of a factor 1000 [1]. This selection of a decimal prefix often permits numerical results to be reported with a numerical value in the recommended interval between 0.1 and 999. For most purposes, the prefixes hecto, deca, deci, and centi can be avoided, though they have equal legal standing.
The prefix symbol and the unit symbol are combined without any space; a second prefix should be avoided in units already containing a prefix; *e.g.* for picogram use pg, not p g or µµg. In units, with a numerator and a denominator, multiple and submultiple shall be in the numerator; *e.g.* the number concentration of thrombocytes in blood should be expressed as $215 \times 10^9$ $L^{-1}$ (not $215 \times 10^6$ $mL^{-1}$) and the substance concentration of arsenic in urine should be expressed as 41 nmol $L^{-1}$ (not 0.041 nmol $mL^{-1}$).
Capital letters are used for the positive powers equal to or greater than mega. This avoids the confusion between mega (symbol M) and milli (symbol m), between peta (symbol P) and pico (symbol p), and between zetta (symbol Z) and zepto (symbol z).

| Prefix with $n \geq 1$ | | | Prefix with $n \leq -1$ | | |
|---|---|---|---|---|---|
| Term | Symbol | $n$* | Term | Symbol | $n$* |
| yotta | Y | 24 | deci | d | –1 |
| zetta | Z | 21 | centi | c | –2 |
| exa | E | 18 | milli | m | –3 |
| peta | P | 15 | micro | µ | –6 |
| tera | T | 12 | nano | n | –9 |
| giga | G | 9 | pico | p | –12 |
| mega | M | 6 | femto | f | –15 |
| kilo | k | 3 | atto | a | –18 |
| hecto | h | 2 | zepto | z | –21 |
| deca | da | 1 | yocto | y | –24 |

*The variable *n* is the decimal exponent of the factor.

## Terminological Rules of the NPU

To avoid misunderstandings, a set of rules is needed for transmission of data about properties:

- The symbol for a **kind-of-quantity** is a single letter (Greek or Latin), printed in italic, with very few exceptions, *e.g.* pH. For each kind-of-quantity, there is only one coherent SI unit. However, the same SI unit may be used to express the values of quantities with different kinds-of-quantity. Therefore, a unit cannot identify the kind-of-quantity; *e.g.* volumic mass and mass concentration use $kg{\cdot}L^{-1}$ , so both the unit and the kind-of-quantity must be stated.

The **kind-of-quantity** and any modifiers may be abbreviated; *e.g.* conc., cont., num., pr., temp., arb., cat., rel., sat. for concentration, content, number, pressure, temperature, arbitrary, catalytic, relative, saturation, respectively [2].

- The symbol for a **unit** is represented by one, two, or three upright lower-case letters, except if the unit is termed after a person; *e.g.* A and K for ampere and kelvin, respectively, and the special case of L for litre. Each term is still written with an initial lower-case letter. In the clinical laboratory, in expressions of volume, the litre and its submultiples are preferred to cubic metre and its submultiples.

- The systematic term for a **component** should not be abbreviated, because abbreviations are not internationally accepted. In the NPU format, the initial letter of the component is a capital letter, except for some prefixes; *e.g.* T4 should be replaced by Thyroxine and α–Amylase is correct. Bacteria, viruses, fungi, plants, and animals including parasites should be designated by their taxonomic term. Terms for genera, species, and subspecies are printed in italic; terms for orders and families, and for strains or races are printed in roman script, but the IFCC data bank of dedicated kinds-of-property uses roman script throughout [10].

Urine(catheter)—Bacterium, nitrite producing; number concentration(procedure) = $2.3 \times 10^6\ L^{-1}$.

Expectorate—Bacterium; taxon = *Mycobacterium tuberculosis*.

- The **system** and any modifiers may be abbreviated; *e.g.* Pt, B, P, U, a, f, v for patient, blood, plasma, urine, arterial, fasting, and venous, respectively [2].

A specific NPU code NPUXXXXX is assigned to each of the 16 000 entries in the NPU data bank [10, 11]. This code is well-adapted to electronic health records or laboratory administrative systems; *e.g.* NPU10547 Pt—Insulin(administered); substance content(i.v.; amount-of-substance/body mass) = 0.3 $\mu mol{\cdot}kg^{-1}$.

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