Special Report

Implementation of SI units for clinical laboratory data: style specifications and conversion tables

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The SI units are now used in many countries to report clinical laboratory data. Through 1987 and 1988 these units will be introduced to replace the various units that have been used until now to report laboratory information in the United States. This action, which has been initiated by the Medical and Health Co-ordinating Group of the American National Metric Council and endorsed by many professional societies including the American Medical Association, will lead to the reporting of clinical laboratory data in molar terms with the liter as the reference volume.

What are SI units?

"SI units" is the abbreviation for *le Système international d'Unités*. These units are the result of over a century of international cooperation to develop a universally acceptable system of units of measurement. The SI is an outgrowth of the metric system that has been widely used throughout most of the world but which has had little impact outside scientific fields in the United States, even though Congress passed the Metric Conversion Act in 1975, which endorsed the SI.

The SI is a uniform system of reporting numerical values permitting interchangeability of information between nations and between disciplines. The SI not only provides a coherent system of units, but also ensures that units are uniform in concept and style. A coherent system is one in which interconversions between the units for different properties requires the factor 1 only. With the SI, quantities can be more easily compared by means of the reduction in the number of multiples and submultiples in common use.

The SI has seven base units from which other units are derived. These seven cornerstones from which the other units have been developed are listed in Table 1, together with the property or physical quantity to which they refer and their official symbol. Appropriate combinations of these base units can be made to express any property although, for simplicity, special names are given to some of the derived units. Representative examples are illustrated in Table 2.

If only base units were used to report clinical laboratory data some test values would be either unmanageably large or small. The SI uses a series of prefixes to the base unit to form decimal multiples and submultiples. The preferred multiples and submultiples change the quantity by increments of 10^3 or 10^{-3} as illustrated in Table 3, but some increments or decrements of less than these factors are occasionally used. These exceptions are included in the box outlined in the table. The symbol for the prefix must be written as in the table and associated without a space with the unit: thus, kilopascal or kPa. For historical reasons the base unit for mass is the kilogram (kg). No prefixes may be combined with this base unit. One thousand kilograms is thus spoken of as 1 megagram (Mg) rather than 1 kilokilogram. Although the correct symbol for micro is μ, it is proposed that u is accepted for use with automatic data processing systems at present.

The SI dictates certain matters of style. Thus symbols are printed in lowercase roman letters except when the name of a unit is derived from a proper name. When a unit derived from a proper name is written in full, not even the first letter is capitalized. The unit for pressure is accordingly pascal but is abbreviated to Pa. L, however, is now an accepted symbol for liter although it is not a proper name. This deviation from normal practice has been done to prevent confusion between the lowercase letter "l" and the numeral "1" which are the same or closely similar in certain type fonts. The SI symbols are never followed by a period, except at the end of a sentence, and never pluralized. A name should not be combined with a symbol. When two or more names or symbols are used together, they should either be spelled out in full or in abbreviated form, but when measured values are printed it is preferable to use symbols for units rather than their complete names. A space must be

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Table 1 Base units of SI

Physical quantity	Base unit	SI symbol
length	meter	m
mass	kilogram	kg
time	second	s
amount of substance	mole	mol
thermodynamic temperature	kelvin	K
electric current	ampere	A
luminous intensity	candela	cd

Table 2 Representative derived units

Derived unit	Name and symbol	Derivation from base units
area	square meter	m^2
volume	cubic meter	m^3
force	newton (N)	$kg \cdot m \cdot s^{-2}$
pressure	pascal (Pa)	$kg \cdot m^{-1} \cdot s^{-2}$ (N/m^2)
work, energy	joule (J)	$kg \cdot m^2 \cdot s^{-2}$ ($N \cdot m$)
mass density	kilogram per cubic meter	kg/m^3
frequency	hertz (Hz)	s^{-1}

Table 3 Prefixes and symbols for decimal multiples and submultiples*

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

* Factors included in the rectangle do not conform to the preferred incremental changes of 10^3 and 10^{-3} but are still used outside medicine.

left between a numeral and symbol—for example, 50 mL and 37 °C. The product of two or more units is indicated by a dot above the line to distinguish it from a decimal point placed on the line. A zero should be placed before a decimal point in a numerical value and decimal numbers should be used in preference to fractions. Spaces should be used to separate long numbers into segments of 3 in both directions from the decimal point; a space is optional with four-digit numbers. Commas should not be used so as to avoid possible confusion with the decimal point, which may be indicated by a comma in some European countries. These style requirements are summarized in Table 4.

SI units in medicine

The immediate rational for reporting laboratory test data in SI units is that this is common practice in much of the world where such units are used on a daily basis in patient-care and in publications from research and other studies. Nevertheless, the underlying reason for a change to SI units is that biological components react in vivo on a molar basis. When all data are expressed in uniform units relating to the actual amount of reactants in moles, a better understanding of the relative amounts of constituents of body fluids and of biological processes and of the interrelationships between different metabolic cycles is possible. When analytes are expressed in mass concentration units, for example, mg, regardless of the denominator or concentration unit, the relative amounts of the substances are obscured. There is seemingly 200 times as much albumin as bilirubin in the icteric neonate who has a serum bilirubin concentration of 20.0 mg/dL and an albumin concentration of 4.0 g/dL. Yet, there is only 1.7 times as much when these same concentrations are stated in molar terms, 340 μmol/L for bilirubin and 580 μmol/L for albumin. The influence of albumin concentration on the binding of bilirubin and other compounds, and the displacement of one compound by another, becomes more apparent.

With the use of SI it is possible to relate the amounts of reactants in different metabolic cycles involving, for example, amino acids, carbohydrates, and fats to each other. It is also possible to see the association of related compounds or metabolites in different tissues, for example, hemoglobin in erythrocytes and plasma, bilirubin and iron in plasma, together with urobilinogen in urine and feces.

Impact of SI units on current medical practice

Although the SI allows the reporting of laboratory data in terms of mass concentration, use of mass units such as mg/L does not indicate the physiologically important amount of an analyte. To do this, units related to the amount of a substance must be used. These are expressed in terms of moles per liter. Although, by derivation, the cubic meter (m^3) should be the reference unit of volume the liter (symbol L), a special name for cubic decimeter (dm^3), has now been accepted as the reference volume. The major changes affecting the reporting of clinical laboratory data are therefore referencing all values to the liter instead of units such as microliter (μL) or deciliter (dL) or 100 mL, and the concept of amount of substance which implies that a measured component will be described in moles or their subunits rather than in mass terms, for example, grams or milligrams. When the molecular mass of a compound is unknown, its concentration will continue to be reported in mass terms (*see* Appendix Table 2).

Table 4 SI Style specifications

Specifications	Example	Incorrect style	Correct style
Use lowercase for symbols or abbreviations	kilogram	Kg	kg
Exceptions:			
	kelvin	k	K
	ampere	a	A
	liter	l	L
Symbols are not followed by period	meter	m.	m
	mole	mol.	mol
Exception: end of sentence			
Do not pluralize symbols	kilograms	kgs	kg
	meters	ms	m
Names and symbols are not to be combined	force	kilogram · meter · s^{-2}	kg · m · s^{-2} kg · m/s^2
When numbers are printed symbols are preferred		100 meters	100 m
		2 moles	2 mol
Space between number and symbol		50ml	50 mL
The product of units is indicated by a dot above the line		kg × m/s^2	kg · m · s^{-2} kg · m/s^2
Only one solidus (/) per expression		mmol/L/s	mmol/(L · s)
Place zero before decimal		.01	0.01
Decimal numbers are preferable to fractions		¾	0.75
		75%	0.75
Spaces are used to separate long numbers		1,500,000	1 500 000
Exception: optional with four-digit number		1,000	1000 or 1 000

The SI uses pascal (Pa) as the unit of pressure, but at present this unit is not recommended to report blood pressure. Nevertheless, it is accepted as the unit for partial pressures of gases instead of mm Hg. The second (s) is the reference unit of time as this is the SI base unit, rather than the often used minute. Although not an SI unit, day (d) is still accepted for long periods of time rather than multiples of the second. The unit katal, abbreviated kat, corresponding to mol/s has been proposed as a special name to report catalytic activity. The Medical and Health Co-ordinating Group of the American National Metric Council recommends the use of kat/L to report enzyme activity because of the complexity of the offical unit mol · s^{-1} · L^{-1} or mol/(s · L) which is both difficult to write and difficult for a computer to print. The new kat/L will replace international units per liter (U/L) as well as the plethora of units based on individuals' names. For those substances whose activity has been reported in terms of standardized biological units—for example, hormones—the same units should continue to be used but with the liter as reference volume.

Thus, the immediate impact on the practice of medicine that implementation of reporting test values in SI units will have is the production of numbers that will initially be unfamiliar to the clinician. When mass concentrations are used, the values will generally be 10 times those with which physicians were familiar.

Implementation of SI units in many other countries has not been associated with problems for patients. Likewise, it should not be a problem in the United States provided all numerical data are *unequivocally* associated with their units. Additionally, it is recommended that numerical values on patient specimens be presented with the appropriate reference range or interval (normal values), at least until physicians have generally become accustomed to SI units.

Special situations

Hematology

With the reference volume becoming the liter, cell count values will increase by 10^6 from those obtained with μL or mm^3 as reference volume. However, the numerical values will remain the same if the multiplication factor is included as part of the unit—for example, × 10^6/L. Although much debate has centered on the reporting of hemoglobin concentrations with mass concentration (g/L) as well as substance concentration with both the monomer, Hb(Fe), the tetramer, Hb(4Fe), being advocated at different times, the International Committee for Standardization in Hematology indicates greater support for expressing hemoglobin as substance concentration in terms of the monomer. At least for the present, the Medical and Health Co-ordinating Group recommends continued use of mass measurement of hemoglobin concentrations, so the reporting unit is g/L.

With the SI, the concept of number fraction replaces percentage. Thus for mass fraction, volume fraction, and relative quantities the unit 1 is used to replace former units. A hematocrit of 45% is reported as 0.45. When electrophoresis of hemoglobin or other blood constituents is done, each component should be reported as a mass fraction—for example, 0.20 rather than 20%. Likewise, the number of cells in a peripheral smear or bone-marrow differential should be ex-

pressed as a number fraction of the total number of cells counted.

Microbiology

Measurements of antibiotics both in serum and as inhibitory concentrations for growth of organisms in the clinical laboratory should be reported in molar units as for other drugs measured in the clinical laboratory. Colony counts should be referenced to the liter as unit of volume; the numerical value will remain unchanged. Bacteria counts on solid media should be references to the gram as denominator unit.

Clinical chemistry

Although drugs may continue to be administered in mass units, their concentrations in body fluids should be reported in molar terms so that these may be understood in relation to the concentration of other analytes. In the long term it is anticipated that drugs will also be administered in molar quantities. A difference in units for administered and measured drugs is not likely to lead to problems as the amount of drug absorbed and active in vivo is substantially different from the amount ingested when given orally. There is a greater rationale for using the same molar units when drugs are given intramuscularly or intravenously.

Although not an SI unit, the osmole should continue to be used for measurements of osmotic pressure rather than a recorded freezing point depression so that clinical understanding is not lessened; results should be expressed in terms of mol/kg. Hormone concentrations should be reported in terms of substance concentration, where possible, but if reported in terms of biological activity, international units (IU) should be used as before but with the liter as reference volume. Where the molecular mass of hormones or proteins is known then the concentrations of these constituents should be reported in moles in preference to grams or their submultiples.

Standardized reporting

Although the SI is only concerned with units of measurement, a major change in reporting practice provides the opportunity to standardize other practices. Certain abbreviations for tissues have been accepted to describe the material on which measurements have been made in many of the countries in which SI units have been adopted. It is proposed that the same abbreviations be implemented in the United States simultaneously with the introduction of SI units. These abbreviations are illustrated in Table 5. However, the Medical and Health Co-ordinating Group recommends that instead of describing a test as, for example, S-glucose or U-calcium, the tests should be stated as glucose (S) and calcium (U), with a single space between the test name and the first parenthesis. This practice highlights the analyte that is measured, rather than the fluid, which recognizes current reporting practices where most results are grouped by fluid analyzed. It also facilitates computerized retrieval and display of data.

Table 5 Recommended abbreviations for tissues and descriptive prefixes*

Amf	amniotic fluid
B	blood
Df	duodenal fluid
Erc	erythrocyte (Ercs = plural)
F	feces
Gf	gastric fluid
H	hair
Lkc	leukocyte (Lkcs = plural)
P	plasma
Perf	peritoneal fluid
Plf	pleural fluid
Pt	patient
S	serum
Semf	seminal fluid
Sf	spinal fluid
Synf	synovial fluid
T	tissue
U	urine
a	arterial
c	capillary
d	day (24 h)
f	fasting
v	venous

* Several of these abbreviations were first used in Canada and have not been used in other countries.

Table 6 Correct symbols for non-SI units of time

min	minute
h	hour
d	day
wk	week
mo	month
y	year

Various prefixes to provide complete definition of a material have also been accepted. These are also included in Table 5. They are used without a space with the abbreviation for a "system" or tissue—for example, aB for arterial blood.

It is recognized that several units are likely to continue in daily use even though they do not conform to the SI and their use in medical practice is discouraged. Standardized symbols have been developed for various units of time. These symbols are listed in Table 6.

Conversion factors

Appendix Tables 1 and 2 list test names and the fluid in which measurements are made together with a typical normal range or reference interval in traditional units. The multiplication factor to convert from current metric to SI units is listed, as is the same reference interval in SI units with the correct symbols for SI units. To convert from SI to conventional units the numerical value in SI units is divided by the conversion factor. The Appendix tables also list the appropriate

Appendix Table 1 SI conversion table for values in clinical hematology

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
erythrocyte count (B)							
—female	3.5–5.0	$10^6/mm^3$	1	3.5–5.0	$10^{12}/L$	X.X	0.1 $10^{12}/L$
—male	4.3–5.9	$10^6/mm^3$	1	4.3–5.9	$10^{12}/L$	X.X	0.1 $10^{12}/L$
erythrocyte count (Sf)	0	mm^{-3}	1	0	$10^6/L$	XX	1 $10^6/L$
erythrocyte sedimentation rate [ESR] (BErc)							
—female	0–30	mm/h	1	0–30	mm/h	XX	1 mm/h
—male	0–20	mm/h	1	0–20	mm/h	XX	1 mm/h
hematocrit (BErcs) vol. fraction							
—female	33–43	%	0.01	0.33–0.43	1	0.XX	0.01
—male	39–49	%	0.01	0.39–0.49	1	0.XX	0.01
hemoglobin (B)							
mass concentration							
—female	12.0–15.0	g/dL	10	120–150	g/L	XXX	1 g/L
—male	13.6–17.2	g/dL	10	136–172	g/L	XXX	1 g/L
substance conc. Hb [Fe]							
—female	12.0–15.0	g/dL	0.6206	7.45–9.30	mmol/L	XX.XX	0.05 mmol/L
—male	13.6–17.2	g/dL	0.6206	8.45–10.65	mmol/L	XX.XX	0.05 mmol/L
leukocyte count (B)	3200–9800	mm^{-3}	0.001	3.2–9.8	$10^9/L$	XX.X	0.1 $10^9/L$
number fraction ["differential"]		%	0.01		1	0.XX	0.01
leukocyte count (Sf)	0–5	mm^{-3}	1	0–5	$10^6/L$	XX	1 $10^6/L$
mean corpuscular hemoglobin [MCH] (BErc)							
mass	27–33	pg	1	27–33	pg	XX	1 pg
amount of substance Hb [Fe]	27–33	pg	0.06206	1.70–2.05	fmol	X.XX	0.05 fmol
mean corpuscular hemoglobin concentration [MCHC] (BErc)							
mass concentration	33–37	g/dL	10	330–370	g/L	XX0	10 g/L
substance conc. Hb [Fe]	33–37	g/dL	0.6206	20–23	mmol/L	XX	1 mmol/L
mean corpuscular volume [MCV] (BErc)							
erythrocyte volume	76–100	μm^3	1	76–100	fL	XXX	1 fL
platelet count (B)	130–400	$10^3/mm^3$	1	130–400	$10^9/L$	XXX	5 $10^9/L$
reticulocyte count (B)—adults	10,000–75,000	mm^{-3}	0.001	10–75	$10^9/L$	XX	1 $10^9/L$
number fraction	1–24	0/00 (number per 1000 erythrocytes)	0.001	0.001–0.024	1	0.XXX	0.001
	0.1–2.4	%	0.001	0.001–0.024	1	0.XXX	0.001

number of significant digits and suggested minimal reporting increments to use so that no greater precision than pertains currently is implied in the data reported in SI units. The reporting intervals and suggested increments are related to the current level of imprecision in the relevant analytical procedures and are not necessarily clinically relevant. The test names listed are preferred over those sometimes used to describe the same analyte as they reflect the state of the analyte under physiological conditions—for example, lactate dehydrogenase rather than lactic dehydrogenase, and pyruvate rather than pyruvic acid.

Note that the reference intervals cited in the Appendix tables, particularly those related to enzyme measurements, may be method dependent and should not be applied uncritically to the data obtained in any laboratory without verification that they are appropriate.

Acknowledgments

Much of the material included here has been based on the *SI Manual in Health Care*, second edition, prepared by the Subcommittee of Metric Commission Canada, Sector 9.10 Health and Welfare, under the chairmanship of Mrs. Genevieve Wilson. That publication includes a comprehensive section on SI units in hematology and clinical chemistry prepared by Dr. M.J. McQueen.

Appendix Table 2 SI conversion factors for values in clinical chemistry

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
acetaminophen (P)—toxic	>5.0	mg/dL	66.16	>330	μmol/L	XX0	10 μmol/L
acetoacetate (S)	0.3–3.0	mg/dL	97.95	30–300	μmol/L	XX0	10 μmol/L
acetone (B,S)	0	mg/dL	172.2	0	μmol/L	XX0	10 μmol/L
acid phosphatase (S)	0–5.5	U/L	16.67	0–90	nkat/L	XX	2 nkat/L
adrenocorticotropin [ACTH] (P)	20–100	pg/mL	0.2202	4–22	pmol/L	XX	1 pmol/L
alanine aminotransferase [ALT] (S)	0–35	U/L	0.01667	0–0.58	μkat/L	X.XX	0.02 μkat/L
albumin (S)	4.0–6.0	g/dL	10.0	40–60	g/L	XX	1 g/L
aldolase (S)	0–6	U/L	16.67	0–100	nkat/L	XX0	20 nkat/L
aldosterone (S)							
normal salt diet	8.1–15.5	ng/dL	27.74	220–430	pmol/L	XX0	10 pmol/L
restricted salt diet	20.8–44.4	ng/dL	27.74	580–1240	pmol/L	XX0	10 pmol/L
aldosterone (U)—sodium excretion							
= 25 mmol/d	18–85	μg/24 h	2.774	50–235	nmol/d	XXX	5 nmol/d
= 75–125 mmol/d	5–26	μg/24 h	2.774	15–70	nmol/d	XXX	5 nmol/d
= 200 mmol/d	1.5–12.5	μg/24 h	2.774	5–35	nmol/d	XXX	5 nmol/d
alkaline phosphatase (S)	30–120	U/L	0.01667	0.5–2.0	μkat/L	X.X	0.1 μkat/L
$alpha_1$-antitrypsin (S)	150–350	mg/dL	0.01	1.5–3.5	g/L	X.X	0.1 g/L
alpha-fetoprotein (S)	0–20	ng/mL	1.00	0–20	μg/L	XX	1 μg/L
alpha-fetoprotein (Amf)	Depends on gestation	mg/dL	10	Depends on gestation	mg/L	XX	1 mg/L
$alpha_2$-macroglobulin (S)	145–410	mg/dL	0.01	1.5–4.1	g/L	X.X	0.1 g/L
aluminum (S)	0–15	μg/L	37.06	0–560	nmol/L	XX0	10 nmol/L
amino acid fractionation (P)							
alanine	2.2–4.5	mg/dL	112.2	245–500	μmol/L	XXX	5 μmol/L
alpha-aminobutyric acid	0.1–0.2	mg/dL	96.97	10–20	μmol/L	XXX	5 μmol/L
arginine	0.5–2.5	mg/dL	57.40	30–145	μmol/L	XXX	5 μmol/L
asparagine	0.5–0.6	mg/dL	75.69	35–45	μmol/L	XXX	5 μmol/L
aspartic acid	0.0–0.3	mg/dL	75.13	0–20	μmol/L	XXX	5 μmol/L
citrulline	0.2–1.0	mg/dL	57.08	15–55	μmol/L	XXX	5 μmol/L
cystine	0.2–2.2	mg/dL	41.61	10–90	μmol/L	XXX	5 μmol/L
glutamic acid	0.2–2.8	mg/dL	67.97	15–190	μmol/L	XXX	5 μmol/L
glutamine	6.1–10.2	mg/dL	68.42	420–700	μmol/L	XXX	5 μmol/L
glycine	0.9–4.2	mg/dL	133.2	120–560	μmol/L	XXX	5 μmol/L
histidine	0.5–1.7	mg/dL	64.45	30–110	μmol/L	XXX	5 μmol/L
hydroxyproline	0–trace	mg/dL	76.26	0–trace	μmol/L	XXX	5 μmol/L
isoleucine	0.5–1.3	mg/dL	76.24	40–100	μmol/L	XXX	5 μmol/L
leucine	1.0–2.3	mg/dL	76.24	75–175	μmol/L	XXX	5 μmol/L
lysine	1.2–3.5	mg/dL	68.40	80–240	μmol/L	XXX	5 μmol/L
methionine	0.1–0.6	mg/dL	67.02	5–40	μmol/L	XXX	5 μmol/L
ornithine	0.4–1.4	mg/dL	75.67	30–400	μmol/L	XXX	5 μmol/L
phenylalanine	0.6–1.5	mg/dL	60.54	35–90	μmol/L	XXX	5 μmol/L
proline	1.2–3.9	mg/dL	86.86	105–340	μmol/L	XXX	5 μmol/L
serine	0.8–1.8	mg/dL	95.16	75–170	μmol/L	XXX	5 μmol/L
taurine	0.3–2.1	mg/dL	79.91	25–170	μmol/L	XXX	5 μmol/L
threonine	0.9–2.5	mg/dL	83.95	75–210	μmol/L	XXX	5 μmol/L
tryptophan	0.5–2.5	mg/dL	48.97	25–125	μmol/L	XXX	5 μmol/L
tyrosine	0.4–1.6	mg/dL	55.19	20–90	μmol/L	XXX	5 μmol/L
valine	1.7–3.7	mg/dL	85.36	145–315	μmol/L	XXX	5 μmol/L
amino acid nitrogen (P)	4.0–6.0	mg/dL	0.7139	2.9–4.3	mmol/L	X.X	0.1 mmol/L
amino acid nitrogen (U)	50–200	mg/24 h	0.07139	3.6–14.3	mmol/d	X.X	0.1 mmol/d
delta-aminolevulinate [as levulinic acid] (U)	1.0–7.0	mg/24 h	7.626	8–53	μmol/d	XX	1 μmol/d
amitriptyline (P,S) —therapeutic	50–200	ng/mL	3.605	180–720	nmol/L	XX0	10 nmol/L
ammonia (vP)							
as ammonia [NH_3]	10–80	μg/dL	0.5872	5–50	μmol/L	XXX	5 μmol/L
as ammonimum iron [NH_4+]	10–85	μg/dL	0.5543	5–50	μmol/L	XXX	5 μmol/L
as nitrogen [N]	10–65	μg/dL	0.7139	5–50	μmol/L	XXX	5 μmol/L
amylase (S)	0–130	U/L	0.01667	0–2.17	μkat/L	XXX	0.01 μkat/L
androstenedione (S)							
—male >18 years	0.2–3.0	μg/L	3.492	0.5–10.5	nmol/L	XX.X	0.5 nmol/L
—female >18 years	0.8–3.0	μg/L	3.492	3.0–10.5	nmol/L	XX.X	0.5 nmol/L

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
angiotensin converting enzyme (S)	<40	nmol/mL/min	16.67	<670	nkat/L	XX0	10 nkat/L
arsenic (H) [as As]	<1	μg/g (ppm)	13.35	<13	nmol/g	XX.X	0.5 nmol/g
arsenic (U) [as As]	0–5	μg/24 h	13.35	0–67	nmol/d	XX	1 nmol/d
[as As_2O_3]	<25	μg/dL	0.05055	<1.3	μmol/L	XX.X	0.1 μmol/L
ascorbate (P) [as ascorbic acid]	0.6–2.0	mg/dL	56.78	30–110	μmol/L	X0	10 μmol/L
aspartate aminotransferase [AST] (S)	0–35	U/L	0.01667	0–0.58	μkat/L	0.XX	0.01 μkat/L
barbiturate (S)—overdose total expressed as:	Depends on composition						
phenobarbital	of mixture.	mg/dL	43.06	. . .	μmol/L	XX	5 μmol/L
sodium phenobarbital	Usually not	mg/dL	39.34		μmol/L	XX	5 μmol/L
barbitone	known.	mg/dL	54.29		μmol/L	XX	5 μmol/L
barbiturate (S)—therapeutic							
see phenobarbital	. . .	. . .	. . .	. . .	. . .	. . .	. .
see pentobarbital							
see thiopental							
bile acids, total (S)							
[as chenodeoxycholic acid]	Trace–3.3	μg/mL	2.547	Trace–8.4	μmol/L	X.X	0.2 μmol/L
cholic acid	Trace–1.0	μg/mL	2.448	Trace–2.4	μmol/L	X.X	0.2 μmol/L
chenodeoxycholic acid	Trace–1.3	μg/mL	2.547	Trace–3.4	μmol/L	X.X	0.2 μmol/L
deoxycholic acid	Trace–1.0	μg/mL	2.547	Trace–2.6	μmol/L	X.X	0.2 μmol/L
lithocholic acid	Trace	μg/mL	2.656	Trace	μmol/L	X.X	0.2 μmol/L
bile acids (Df) [after cholecystokinin stimulation]							
total as chenodeoxycholic acid	14.0–58.0	mg/mL	2.547	35.0–148.0	mmol/L	XX.X	0.2 mmol/L
cholic acid	2.4–33.0	mg/mL	2.448	6.8–81.0	mmol/L	XX.X	0.2 mmol/L
chenodeoxycholic acid	4.0–24.0	mg/mL	2.547	10.0–61.4	mmol/L	XX.X	0.2 mmol/L
deoxycholic acid	0.8–6.9	mg/mL	2.547	2.0–18.0	mmol/L	XX.X	0.2 mmol/L
lithocholic acid	0.3–0.8	mg/mL	2.656	0.8–2.0	mmol/L	XX.X	0.2 mmol/L
bilirubin, total (S)	0.1–1.0	mg/dL	17.10	2–18	μmol/L	XX	2 μmol/L
bilirubin, conjugated (S)	0–0.2	mg/dL	17.10	0–4	μmol/L	XX	2 μmol/L
bromide (S), toxic							
—as bromide ion	>120	mg/dL	0.1252	>15	mmol/L	XX	1 mmol/L
—as sodium bromide	>150	mg/dL	0.09719	>15	mmol/L	XX	1 mmol/L
	>15	mEq/L	1.00	>15	mmol/L	XX	1 mmol/L
cadmium (S)	<3	μg/dL	0.08897	<0.3	μmol/L	X.X	0.1 μmol/L
calcitonin (S)	<100	pg/mL	1.00	<100	ng/L	XXX	10 ng/L
calcium (S)							
—male	8.8–10.3	mg/dL	0.2495	2.20–2.58	mmol/L	X.XX	0.02 mmol/L
—female <50 y	8.8–10.0	mg/dL	0.2495	2.20–2.50	mmol/L	X.XX	0.02 mmol/L
—female >50 y	8.8–10.2	mg/dL	0.2495	2.20–2.56	mmol/L	X.XX	0.02 mmol/L
	4.4–5.1	mEq/L	0.500	2.20–2.56	mmol/L	X.XX	0.02 mmol/L
calcium ion (S)	2.00–2.30	mEq/L	0.500	1.00–1.15	mmol/L	X.XX	0.01 mmol/L
	4.00–4.60	mg/dL	0.2495	1.00–1.15	mmol/L	X.XX	0.01 mmol/L
calcium (U), normal diet	<250	mg/24 h	0.02495	<6.2	mmol/d	X.X	0.1 mmol/d
carbamazepine (P)—therapeutic	4.0–10.0	mg/L	4.233	17–42	μmol/L	XX	1 μmol/L
carbon dioxide content (B,P,S) [bicarbonate + CO_2]	22–28	mEq/L	1.00	22–28	mmol/L	XX	1 mmol/L
carbon monoxide (B) [proportion of Hb which is COHb]	<15	%	0.01	<0.15	1	0.XX	0.01
beta-carotenes (S)	50–250	μg/dL	0.01863	0.9–4.6	μmol/L	X.X	0.1 μmol/L
catecholamines, total (U) [as norepinephrine]	<120	μg/24 h	5.911	<675	nmol/d	XX0	10 mg/d
ceruloplasmin (S)	20–35	mg/dL	10.0	200–350	mg/L	XX0	10 mg/L
chlordiazepoxide (P)							
—therapeutic	0.5–5.0	mg/L	3.336	2–17	μmol/L	XX	1 μmol/L
—toxic	>10.0	mg/L	3.336	>33	μmol/L	XX	1 μmol/L
chloride (S)	95–105	mEq/L	1.00	95–105	mmol/L	XXX	1 mmol/L
chlorimipramine (P) [includes desmethyl metabolite]	50–400	ng/mL	3.176	150–1270	nmol/L	XX0	10 nmol/L

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
chlorpromazine (P)	50–300	ng/mL	3.136	150–950	nmol/L	XX0	10 nmol/L
chlorpropamide (P)— therapeutic	75–250	mg/L	3.613	270–900	μmol/L	XX0	10 μmol/L
cholestanol (P)—[as a fraction of total cholesterol]	1–3	%	0.01	0.01–0.03	1	0.XX	0.01
cholesterol (P)							
—<29 years	<200	mg/dL	0.02586	<5.20	mmol/L	X.XX	0.05 mmol/L
—30–39 years	<225	mg/dL	0.02586	<5.85	mmol/L	X.XX	0.05 mmol/L
—40–49 years	<245	mg/dL	0.02586	<6.35	mmol/L	X.XX	0.05 mmol/L
—>50 years	<265	mg/dL	0.02586	<6.85	mmol/L	X.XX	0.05 mmol/L
cholesterol esters (P) [as a fraction of total cholesterol]	60–75	%	0.01	0.60–0.75	1	0.XX	0.01
cholinesterase (S)	620–1370	U/L	0.01667	10.3–22.8	μkat/L	XX.X	0.1 μkat/L
chorionic gonadotrophin (P) [beta-HCG]	0 if not pregnant	mIU/mL	1.00	0 if not pregnant	IU/L	XX	1 IU/L
citrate (B) [as citric acid]	1.2–3.0	mg/dL	52.05	60–160	μmol/L	XXX	5 μmol/L
complement, C3 (S)	70–160	mg/dL	0.01	0.7–1.6	g/L	X.X	0.1 g/L
complement, C4 (S)	20–40	mg/dL	0.01	0.2–0.4	g/L	X.X	0.1 g/L
copper (S)	70–140	μg/dL	0.1574	11.0–22.0	μmol/L	XX.X	0.2 μmol/L
copper (U)	<40	μg/24 h	0.01574	<0.6	μmol/d	X.X	0.2 μmol/d
coproporphyrins (U)	<200	μg/24 h	1.527	<300	nmol/d	XX0	10 nmol/d
cortisol (S)							
—0800 h	4–19	μg/dL	27.59	110–520	nmol/L	XX0	10 nmol/L
—1600 h	2–15	μg/dL	27.59	50–410	nmol/L	XX0	10 nmol/L
—2400 h	5	μg/dL	27.59	140	nmol/L	XX0	10 nmol/L
cortisol, free (U)	10–110	μg/24 h	2.759	30–300	nmol/d	XX0	10 nmol/d
creatine (S)							
—male	0.17–0.50	mg/dL	76.25	10–40	μmol/L	X0	10 μmol/L
—female	0.35–0.93	mg/dL	76.25	30–70	μmol/L	X0	10 μmol/L
creatine (U)							
—male	0–40	mg/24 h	7.625	0–300	μmol/d	XX0	10 μmol/d
—female	0–80	mg/24 h	7.625	0–600	μmol/d	XX0	10 μmol/d
creatine kinase [CK] (S)							
creatine kinase isoenzymes (S)	1–130	U/L	0.01667	0–2.16	μkat/L	X.XX	0.01 μkat/L
—MB fraction	>5 in myocardial infarction	%	0.01	>0.05	1	0.XX	0.01
creatinine (S)	0.6–1.2	mg/dL	88.40	50–110	μmol/L	XX0	10 μmol/L
creatinine (U)	Variable	g/24 h	8.840	Variable	mmol/d	XX.X	0.1 mmol/d
creatinine clearance (S,U)	75–125 creatinine clearance corrected for body surface area	mL/min	0.01667	1.24–2.08	mL/s	X.XX	0.02 mL/s
			$= \frac{\mu mol/L\ (urine\ creatinine)}{\mu mol/L\ (serum\ creatinine)} \times mL/s \times \frac{1.73}{A}$ [where A is the body surface area in square meters (m^2)]				
cyanide (B)—lethal	>0.10	mg/dL	384.3	>40	μmol/L	XXX	5 μmol/L
cyanocobalamin (S) [vitamin B_{12}]	200–1000	pg/mL	0.7378	150–750	pmol/L	XX0	10 pmol/L
cyclic AMP (S)	2.6–6.6	μg/L	3.038	8–20	nmol/L	XXX	1 nmol/L
cyclic AMP (U)							
—total urinary	2.9–5.6	μmol/g creatinine	113.1	330–630	nmol/mmol creatinine	XX0	10 nmol/mmol creatinine
—renal tubular	<2.5	μmol/g creatinine	113.1	<280	nmol/mmol creatinine	XX0	10 nmol/mmol creatinine
cyclic GMP (S)	0.6–3.5	μg/L	2.897	1.7–10.1	nmol/L	XX.X	0.1 nmol/L
cyclic GMP (U)	0.3–1.8	μmol/g creatinine	113.1	30–200	nmol/mmol creatinine	XX0	10 nmol/mmol creatinine
cystine (U)	10–100	mg/24 h	4.161	40–420	μmol/d	XX0	10 μmol/d
dehydroepiandrosterone (P,S)							
[DHEA]—1–4 years	0.2–0.4	μg/L	3.467	0.6–1.4	nmol/L	XX.X	0.2 nmol/L
4–8 years	0.1–1.9	μg/L	3.467	0.4–6.6	nmol/L	XX.X	0.2 nmol/L
8–10 years	0.2–2.9	μg/L	3.467	0.6–10.0	nmol/L	XX.X	0.2 nmol/L
10–12 years	0.5–9.2	μg/L	3.467	1.8–31.8	nmol/L	XX.X	0.2 nmol/L
12–14 years	0.9–20.0	μg/L	3.467	3.2–69.4	nmol/L	XX.X	0.2 nmol/L
14–16 years	2.5–20.0	μg/L	3.467	8.6–69.4	nmol/L	XX.X	0.2 nmol/L

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
premenopausal female	2.0–15.0	μg/L	3.467	7.0–52.0	nmol/L	XX.X	0.2 nmol/L
male	0.8–10.0	μg/L	3.467	2.8–34.6	nmol/L	XX.X	0.2 nmol/L
dehydroepiandrosterone (U)	*See* Steroids	Fractionation	. . .	. . .	. .	. . .	. . .
dehydroepiandrosterone sulphate [DHEA-S] (P,S)							
newborn	1670–3640	ng/mL	0.002714	4.5–9.9	μmol/L	XX.X	0.1 μmol/L
pre-pubertal children	100–600	ng/mL	0.002714	0.3–1.6	μmol/L	XX.X	0.1 μmol/L
male	2000–3350	ng/mL	0.002714	5.4–9.1	μmol/L	XX.X	0.1 μmol/L
female [premenopausal]	820–3380	ng/mL	0.002714	2.2–9.2	μmol/L	XX.X	0.1 μmol/L
female [post-menopausal]	110–610	ng/mL	0.002714	0.3–1.7	μmol/L	XX.X	0.1 μmol/L
pregnancy [term]	230–1170	ng/mL	0.002714	0.6–3.2	μmol/L	XX.X	0.1 μmol/L
11-deoxycortisol (S)	0–2	μg/dL	28.86	0–60	nmol/L	XX0	10 nmol/L
desipramine (P)— therapeutic	50–200	ng/mL	3.754	170–700	nmol/L	XX0	10 nmol/L
diazepam (P)							
—therapeutic	0.10–0.25	mg/L	3512	350–900	nmol/L	XX0	10 nmol/L
—toxic	>1.0	mg/L	3512	>3510	nmol/L	XX0	10 nmol/L
dicoumarol (P)— therapeutic	8–30	mg/L	2.974	25–90	μmol/L	XX	5 μmol/L
digoxin (P)							
—therapeutic	0.5–2.2	ng/mL	1.281	0.6–2.8	nmol/L	X.X	0.1 nmol/L
	0.5–2.2	μg/L	1.281	0.6–2.8	nmol/L	X.X	0.1 nmol/L
—toxic	>2.5	ng/mL	1.281	>3.2	nmol/L	X.X	0.1 nmol/L
dimethadione (P)— therapeutic	<1.00	g/L	7.745	<7.7	mmol/L	X.X	0.1 mmol/L
disopyramide (P)— therapeutic	2.0–6.0	mg/L	2.946	6–18	μmol/L	XX	1 μmol/L
doxepin (P)—therapeutic	50–200	ng/mL	3.579	180–720	nmol/L	XX0	10 nmol/L
electrophoresis, protein (S)							
albumin	60–65	%	0.01	0.60–0.65	1	0.XX	0.01
alpha$_1$-globulin	1.7–5.0	%	0.01	0.02–0.05	1	0.XX	0.01
alpha$_2$-globulin	6.7–12.5	%	0.01	0.07–0.13	1	0.XX	0.01
beta-globulin	8.3–16.3	%	0.01	0.08–0.16	1	0.XX	0.01
gamma-globulin	10.7–20.0	%	0.01	0.11–0.20	1	0.XX	0.01
albumin	3.6–5.2	g/dL	10.0	36–52	g/L	XX	1 g/L
alpha$_1$-globulin	0.1–0.4	g/dL	10.0	1–4	g/L	XX	1 g/L
alpha$_2$-globulin	0.4–1.0	g/dL	10.0	4–10	g/L	XX	1 g/L
beta-globulin	0.5–1.2	g/dL	10.0	5–12	g/L	XX	1 g/L
gamma-globulin	0.6–1.6	g/dL	10.0	6–16	g/L	XX	1 g/L
epinephrine (P)	31–95 (at rest for 15 min)	pg/mL	5.458	170–520	pmol/L	XX0	10 pmol/L
epinephrine (U)	<10	μg/24 h	5.458	<55	nmol/d	XX	5 nmol/d
estradiol (S)—male >18 years	15–40	pg/mL	3.671	55–150	pmol/L	XXX	1 pmol/L
estriol (U) [non-pregnant]							
onset of menstruation	4–25	μg/24 h	3.468	15–85	nmol/d	XXX	5 nmol/d
ovulation peak	28–99	μg/24 h	3.468	95–345	nmol/d	XXX	5 nmol/d
luteal peak	22–105	μg/24 h	3.468	75–365	nmol/d	XXX	5 nmol/d
menopausal women	1.4–19.6	μg/24 h	3.468	5–70	nmol/d	XXX	5 nmol/d
male	5–18	μg/24 h	3.468	15–60	nmol/d	XXX	5 nmol/d
estrogens (S) [as estradiol]							
female	20–300	pg/mL	3.671	70–1100	pmol/L	XXX0	10 pmol/L
peak production	200–800	pg/mL	3.671	750–2900	pmol/L	XXX0	10 pmol/L
male	<50	pg/mL	3.671	<180	pmol/L	XX0	10 pmol/L
estrogens, placental (U) [as estriol]	Depends on period of gestation	mg/24 h	3.468	Depends on period of gestation	μmol/d	XXX	1 μmol/d
estrogen receptors (T)							
negative	0–3	fmol estradiol bound/mg cytosol protein	1.00	0–3	fmol estradiol/mg cytosol protein	XXX	1 fmol/mg protein

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
doubtful	4–10	fmol estradiol bound/mg cytosol protein	1.00	4–10	fmol estradiol/mg cytosol protein	XXX	fmol/mg protein
positive	>10	fmol estradiol bound/mg cytosol protein	1.00	>10	fmol estradiol/mg cytosol protein	XXX	fmol/mg protein
estrone (P,S)							
—female 1–10 days of cycle	43–180	pg/mL	3.699	160–665	pmol/L	XXX	5 pmol/L
—female 11–20 days of cycle	75–196	pg/mL	3.699	275–725	pmol/L	XXX	5 pmol/L
—female 20–39 days of cycle	131–201	pg/mL	3.699	485–745	pmol/L	XXX	5 pmol/L
—male	29–75	pg/mL	3.699	105–275	pmol/L	XXX	5 pmol/L
estrone (U)—female	2–25	μg/24 h	3.699	5–90	nmol/d	XXX	5 nmol/d
ethanol (P)							
legal limit [driving]	<80	mg/dL	0.2171	<17	mmol/L	XX	1 mmol/L
—toxic	>100	mg/dL	0.2171	>22	mmol/L	XX	1 mmol/L
ethchlorvynol (P)—toxic	>40	mg/L	6.915	>280	μmol/L	XX0	10 μmol/L
ethosuximide (P)—							
therapeutic	40–110	mg/L	7.084	280–780	μmol/L	XX0	10 μmol/L
ethylene glycol (P)—toxic	>30	mg/dL	0.1611	>5	mmol/L	XX	1 mmol/L
fat (F) [as stearic acid]	2.0–6.0	g/24 h	3.515	7–21	mmol/d	XX	1 mmol/d
fatty acids, non-esterified (P)	8–20	mg/dL	10.00	80–200	mg/L	XX0	10 mg/L
ferritin (S)	18–300	ng/mL	1.00	18–300	μg/L	XX0	10 μg/L
fibrinogen (P)	200–400	mg/dL	0.01	2.0–4.0	g/L	X.X	0.1 g/L
fluoride (U)	<1.0	mg/24 h	52.63	<50	μmol/d	XX0	10 μmol/d
folate (S) [as pteroyl-glutamic acid]	2–10	ng/mL μg/dL	2.266 22.66	4–22	nmol/L nmol/L	XX	2 nmol/L 2 nmol/L
folate (Erc)	140–960	ng/mL	2.266	550–2200	nmol/L	XX0	10 nmol/L
follicle stimulating hormone [FSH] (P)							
female	2.0–15.0	mIU/mL	1.00	2–15	IU/L	XX	1 IU/L
peak production	20–50	mIU/mL	1.00	20–50	IU/L	XX	1 IU/L
male	1.0–10.0	mIU/mL	1.00	1–10	IU/L	XX	1 IU/L
follicle stimulating hormone [FSH] (U)							
follicular phase	2–15	IU/24 h	1.00	2–15	IU/d	XXX	1 IU/d
midcycle	8–40	IU/24 h	1.00	8–40	IU/d	XXX	1 IU/d
luteal phase	2–10	IU/24 h	1.00	2–10	IU/d	XXX	1 IU/d
menopausal women	35–100	IU/24 h	1.00	35–100	IU/d	XXX	1 IU/d
male	2–15	IU/24 h	1.00	2–15	IU/d	XXX	1 IU/d
fructose (P)	<10	mg/dL	0.05551	<0.6	mmol/L	X.XX	0.1 mmol/L
galactose (P) [children]	<20	mg/dL	0.05551	<1.1	mmol/L	X.XX	0.1 mmol/L
gases (aB)							
$_{a}O_2$	75–105	mm Hg (= Torr)	0.1333	10.0–14.0	kPa	XX.X	0.1 kPa
$_{a}CO_2$	33–44	mm Hg (= Torr)	0.1333	4.4–5.9	kPa	X.X	0.1 kPa
gamma-glutamyltransferase [GGT] (S)	0–30	U/L	0.01667	0–0.50	μkat/L	X.XX	0.01 μkat/L
gastrin (S)	0–180	pg/mL	1	0–180	ng/L	XX0	10 ng/L
globulins (S) [see immuno-globulins]	. . .	. . .	. . .	. . .	. . .	. . .	. . .
glucagon (S)	50–100	pg/mL	1	50–100	ng/L	XX0	10 ng/L
glucose (P)—fasting	70–110	mg/dL	0.05551	3.9–6.1	mmol/L	XX.X	0.1 mmol/L
glucose (Sf)	50–80	mg/dL	0.05551	2.8–4.4	mmol/L	XX.X	0.1 mmol/L
glutethimide (P)							
—therapeutic	<10	mg/L	4.603	<46	μmol/L	XX	1 μmol/L
—toxic	>20	mg/L	4.603	>92	μmol/L	XX	1 μmol/L
glycerol, free (S)	<1.5	mg/dL	0.1086	<0.16	mmol/L	X.XX	0.01 mmol/L
gold (S)—therapeutic	300–800	μg/dL	0.05077	15.0–40.0	μmol/L	XX.X	0.1 μmol/L
gold (U)	<500	μg/24 h	0.005077	<2.5	μmol/d	X.X	0.1 μmol/d

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
growth hormone (P,S)							
male [fasting]	0.0–5.0	ng/mL	1.00	0.0–5.0	μg/L	XX.X	0.5 μg/L
female [fasting]	0.0–10.0	ng/mL	1.00	0.0–10.0	μg/L	XX.X	0.5μg/L
haptoglobin (S)	50–220	mg/dL	0.01	0.50–2.20	g/L	X.XX	0.01 g/L
hemoglobin (B)							
—male	14.0–18.0	g/dL	10.0	140–180	g/L	XXX	1 g/L
—female	11.5–15.5	g/dL	10.0	115–155	g/L	XXX	1 g/L
[see Hematology section, Appendix 1(a)]							
homogentisate (U)							
as homogentisic acid]	0	mg/24 h	5.947	0	μmol/d	XX	5 μmol/d
homovanillate (U)							
[as homovanillic acid]	<8	mg/24 h	5.489	<45	μmol/d	XX	5 μmol/d
beta-hydroxybutyrate (S)							
[as beta-hydroxybutyric acid]	<1.0	mg/dL	96.05	<100	μmol/L	XX0	10 μmol/L
5-hydroxyindoleacetate (U)							
[as 5-hydroxyindole acetic acid; 5 HIAA]	2–8	mg/24 h	5.230	10–40	μmol/d	XXX	5 μmol/d
17-alpha-hydroxy-progesterone (S,P)							
—children	0.2–1.4	μg/L	3.026	0.5–4.5	nmol/L	XX.X	0.5 nmol/L
—male	0.5–2.5	μg/L	3.026	1.5–7.5	nmol/L	XX.X	0.5 nmol/L
—female	0.3–4.2	μg/L	3.026	1.0–13.0	nmol/L	XX.X	0.5 nmol/L
—female, postmenopausal	0.3–1.7	μg/L	3.026	1.0–5.0	nmol/L	XX.X	0.5 nmol/L
hydroxyproline (U)							
—1 wk–1 y	55–220	mg/24 h/m^2	7.626	420–1680	μmol/(d · m^2)	XX0	10 μmol/(d · m^2)
—1–13 y	25–80	mg/24 h/m^2	7.626	190–610	μmol/(d · m^2)	XX0	10 μmol/(d · m^2)
—22–65 y	6–22	mg/24 h/m^2	7.626	40–170	μmol/(d · m^2)	XX0	10 μmol/(d · m^2)
—>65 y	5–17	mg/24 h/m^2	7.626	40–130	μmol/(d · m^2)	XX0	10 μmol/(d · m^2)
immunoglobulins (S)							
IgG	500–1200	mg/dL	0.01	5.00–12.00	g/L	XX.XX	0.01 g/L
IgA	50–350	mg/dL	0.01	0.50–3.50	g/L	XX.XX	0.01 g/L
IgM	30–230	mg/dL	0.01	0.30–2.30	g/L	XX.XX	0.01 g/L
IgD	<6	mg/dL	10	<60	mg/L	XX0	10 mg/L
IgE—0–3 years	0.5–10	IU/mL	2.4	1–24	μg/L	XX	1 μg/L
—3–80 years	5–100	IU/mL	2.4	12–240	μg/L	XX	1 μg/L
imipramine (P)—therapeutic	50–200	ng/mL	3.566	180–710	nmol/L	XX0	10 nmol/L
insulin (P,S)	5–20	μU/mL	7.175	35–145	pmol/L	XXX	5 pmol/L
	5–20	mU/L	7.175	35–145	pmol/L	XXX	5 pmol/L
	0.20–0.84	μg/mL	172.2	35–145	pmol/L	XXX	5 pmol/L
iron (S)							
—male	80–180	μg/dL	0.1791	14–32	μmol/L	XX	1 μmol/L
—female	60–160	μg/dL	0.1791	11–29	μmol/L	XX	1 μmol/L
iron binding capacity (S)	250–460	μg/dL	0.1791	45–82	μmol/L	XX	1 μmol/L
isoniazid (P)							
—therapeutic	<2.0	mg/L	7.291	<15	μmol/L	XX	1 μmol/L
—toxic	>3.0	mg/L	7.291	>22	μmol/L	XX	1 μmol/L
isopropanol (P)	0	mg/dL	0.1664	0	mmol/L	XX	1 mmol/L
lactate (P) [as lactic acid]	0.5–2.0	mEq/L	1.00	0.5–2.0	mmol/L	X.X	0.1 mmol/L
	5–20	mg/dL	0.1110	0.5–2.0	mmol/L	X.X	0.1 mmol/L
lactate dehydrogenase (S)	50–150	U/L	0.01667	0.82–2.66	μkat/L	X.XX	0.02 μkat/L
lactate dehydrogenase isoenzymes (S)							
—LD1	15–40	%	0.01	0.15–0.40	1	0.XX	0.01
—LD2	20–45	%	0.01	0.20–0.45	1	0.XX	0.01
—LD3	15–30	%	0.01	0.15–0.30	1	0.XX	0.01
—LD4	5–20	%	0.01	0.05–0.20	1	0.XX	0.01
—LD5	5–20	%	0.01	0.05–0.20	1	0.XX	0.01
—LD1	10–60	U/L	0.01667	0.16–1.00	μkat/L	X.XX	0.02 μkat/L
—LD2	20–70	U/L	0.01667	0.32–1.16	μkat/L	X.XX	0.02 μkat/L

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
—LD3	10–45	U/L	0.01667	0.22–0.76	μkat/L	X.XX	0.02 μkat/L
—LD4	5–30	U/L	0.01667	0.08–0.50	μkat/L	X.XX	0.02 μkat/L
—LD5	5–30	U/L	0.01667	0.02–0.50	μkat/L	X.XX	0.02 μkat/L
lead (B)—toxic	>60	μg/dL	0.04826	>2.90	μmol/L	X.XX	0.05 μmol/L
		mg/dL	48.26		μmol/L	X.XX	0.05 μmol/L
lead (U)—toxic	>80	μg/24 h	0.004826	>0.40	μmol/d	X.XX	0.05 μmol/d
lidocaine (P) [Xylocaine]	1.0–5.0	mg/L	4.267	4.5–21.5	μmol/L	X.X	0.5 μmol/L
lipase (S)	0–160	U/L	0.01667	0–2.66	μkat/L	X.XX	0.02 μkat/L
lipids, total (P)	400–850	mg/dL	0.01	4.0–8.5	g/L	X.X	0.1 g/L
lipoproteins (P)							
low density [LDL]—as cholesterol	50–190	mg/dL	0.02586	1.30–4.90	mmol/L	X.XX	0.05 mmol/L
high density [HDL]—as *cholesterol*							
male	30–70	mg/dL	0.02586	0.80–1.80	mmol/L	X.XX	0.05 mmol/L
female	30–90	mg/dL	0.02586	0.80–2.35	mmol/L	X.XX	0.05 mmol/L
lithium ion (S)—therapeutic	0.50–1.50	mEq/L	1.00	0.50–1.50	mmol/L	X.XX	0.05 mmol/L
		μg/dL	0.001441		mmol/L	X.XX	0.05 mmol/L
		mg/dL	1.441		mmol/L	X.XX	0.05 mmol/L
luteinizing hormone (S)							
—male	3–25	mIU/mL	1.00	3–25	IU/L	XXX	1 IU/L
—female	2–20	mIU/mL	1.00	2–20	IU/L	XXX	1 IU/L
—peak production	30–140	mIU/mL	1.00	30–140	IU/L	XXX	1 IU/L
lysozyme (S) [muramidase]	1–15	μg/mL	1.00	1–15	mg/L	XXX	1 mg/L
lysozyme (U) [muramidase]	<2	μg/mL	1.00	<2	mg/L	XX	1 mg/L
magnesium (S)	1.8–3.0	mg/dL	0.4114	0.80–1.20	mmol/L	X.XX	0.02 mmol/L
	1.6–2.4	*mEq/L*	0.500	0.80–1.20	*mmol/L*	X.XX	0.02 mmol/L
maprotiline (P)— therapeutic	50–200	ng/mL	3.605	180–720	nmol/L	XX0	10 nmol/L
meprobamate (P)							
—therapeutic	<20	mg/L	4.582	<90	μmol/L	XX0	10 μmol/L
—toxic	>40	mg/L	4.582	>180	μmol/L	XX0	10 μmol/L
mercury (B)							
—normal	<1.0	μg/dL	49.85	<50	nmol/L	XX0	10 nmol/L
—chronic exposure	>20	μg/dL	0.04985	>1.00	μmol/L	X.XX	0.01μmol/L
mercury (U)							
—normal	<30	μg/24 h	4.985	<150	nmol/d	XX0	10 nmol/d
—exposure—organic	>45	μg/24 h	4.985	>220	nmol/d	XX0	10 nmol/d
—inorganic	>450	μg/24 h	0.004985	>2.20	μmol/d	X.XX	0.01 μmol/d
metanephrines (U)							
[as normetanephrine]	0–2.0	mg/24 h	5.458	0–11.0	μmol/d	XX.X	0.5 μmol/d
methanol (P)	0	mg/dL	0.3121	0	mmol/L	XX	1 mmol/L
methaqualone (P)							
—therapeutic	<10	mg/L	3.995	<40	μmol/L	XX0	10 μmol/L
—toxic	>30	mg/L	3.995	>120	μmol/L	XX0	10 μmol/L
methotrexate (S)—toxic	>2.3	mg/L	2.200	>5.0	μmol/L	X.X	0.1 μmol/L
methsuximide (P) [as desmethylsuximide]							
—therapeutic	10–40	mg/L	5.285	50–210	μmol/L	XX0	10 μmol/L
methyprylon (P)							
—therapeutic	<10	mg/L	5.457	<50	μmol/L	XX0	10 μmol/L
—toxic	>40	mg/L	5.457	>220	μmol/L	XX0	10 μmol/L
$beta_2$-microglobulin (S)—<50 y	0.80–2.40	mg/L	84.75	68–204	nmol/L	XXX	2 nmol/L
$beta_2$-microglobulin (U)—<50 y	<140	μg/24 h	0.08475	<12	nmol/d	XXX	2 nmol/L
nitrogen, total (U)	Diet dependent	g/24 h	71.38	Diet dependent	mmol/d	XX0	10 mmol/d
norepinephrine (P)	15–475 (*at* rest for 15 min)	*pg/mL*	0.005911	1.27–2.81	*nmol/L*	X.XX	0.01 *nmol/L*
norepinephrine (U)	<100	μg/24 h	5.911	<590	nmol/d	XX0	10 nmol/d
nortriptyline (P)—therapeutic	25–200	ng/mL	3.797	90–760	nmol/L	XX0	10 nmol/L
osmolality (P)	280–300	mOsm/kg	1.00	280–300	mmol/kg	XXX	1 mmol/kg
osmolality (U)	50–1200	mOsm/kg	1.00	50–1200	mmol/kg	XXX	1 mmol/kg
oxalate (U) [as anhydrous oxalic acid]	10–40	mg/24 h	11.11	110–440	μmol/d	XX0	10 μmol/d

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
palmitic acid (Amf)	Depends on gestation	mmol/L	1000	Depends on gestation	μmol/L	XXX	5 μmol/L
pentobarbital (P)	20–40	mg/L	4.419	90–170	μmol/L	XX	5 μmol/L
phenobarbital (P)—therapeutic	2–5	mg/dL	43.06	85–215	μmol/L	XXX	5 μmol/L
phensuximide (P)	4–8	mg/L	5.285	20–40	μmol/L	XX	5 μmol/L
phenylbutazone (P)— therapeutic	<100	mg/L	3.243	<320	μmol/L	XX0	10 μmol/L
phenytoin (P)							
—therapeutic	10–20	mg/L	3.964	40–80	μmol/L	XX	5 μmol/L
—toxic	>30	mg/L	3.964	>120	μmol/L	XX	5 μmol/L
phosphate (S) [as phosphorus, inorganic]	2.5–5.0	mg/dL	0.3229	0.80–1.60	mmol/L	X.XX	0.05 mmol/L
phosphate (U) [as phosphorus, inorganic]	Diet dependent	g/24 h	32.29	Diet dependent	mmol/d	XXX	1 mmol/d
phospholipid phosphorus, total (P)	5–12	mg/dL	0.3229	1.60–3.90	mmol/L	X.XX	0.05 mmol/L
phospholipid phosphorus, total (Erc)	1.2–12	mg/dL	0.3229	0.40–3.90	mmol/L	X.XX	0.05 mmol/L
phospholipids (P)— substance fraction of total phospholipid							
phosphatidyl choline	65–70	% of total	0.01	0.65–0.70	1	0.XX	0.01
phosphatidyl ethanolamine	4–5	% of total	0.01	0.04–0.05	1	0.XX	0.01
sphingomyelin	15–20	% of total	0.01	0.15–0.20	1	0.XX	0.01
lysophosphatidyl choline	3–5	% of total	0.01	0.03–0.05	1	0.XX	0.01
phospholipids (Erc)— substance fraction of total phospholipid							
phosphatidyl choline	28–33	% of total	0.01	0.28–0.33	1	0.XX	0.01
phosphatidyl ethanolamine	24–31	% of total	0.01	0.24–0.31	1	0.XX	0.01
sphingomyelin	22–29	% of total	0.01	0.22–0.29	1	0.XX	0.01
phosphatidyl serine + phosphatidyl inositol	12–20	% of total	0.01	0.12–0.20	1	0.XX	0.01
lysophosphatidyl choline	1–2	% of total	0.01	0.01–0.02	1	0.XX	0.01
phytanic acid (P)	Trace—0.3	mg/dL	32.00	<10	μmol/L	XX	5 μmol/L
[human] placental lactogen (S) [HPL]	>4.0 after 30 wk gestation	μg/mL	46.30	>180	nmol/L	XX0	10 nmol/L
porphobilinogen (U)	0.0–2.0	mg/24 h	4.420	0–9.0	μmol/d	X.X	0.5 μmol/d
porphyrins							
coproporphyrin (U)	45–180	μg/24 h	1.527	68–276	nmol/d	XXX	2 nmol/d
protoporphyrin (Erc)	15–50	μg/dL	0.0177	0.28–0.90	μmol/L	X.XX	0.02 μmol/L
uroporphyrin (U)	5–20	μg/24 h	1.204	6–24	nmol/d	XX	2 nmol/d
uroporphyrinogen synthetase (Erc)	22–42	mmol/mL/h	0.2778	6.0–11.8	mmol/(L · s)	X.X	0.2 mmol/(L · s)
potassium ion (S)	3.5–5.0	mEq/L	1.00	3.5–5.0	mmol/L	X.X	0.1 mmol/L
		mg/dL	0.2558		mmol/L	X.X	0.1 mmol/L
potassium ion (U) [diet dependent]	25–100	mEq/24 h	1.00	25–100	mmol/d	XX	1 mmol/d
pregnanediol (U)							
—normal	1.0–6.0	mg/24 h	3.120	3.0–18.5	μmol/d	XX.X	0.5 μmol/d
—pregnancy	Depends on gestation						
pregnanetriol (U)	0.5–2.0	mg/24 h	2.972	1.5–6.0	μmol/d	XX.X	0.5 μmol/d
primidone (P)							
—therapeutic	6.0–10.0	mg/L	4.582	25–46	μmol/L	XX	1 μmol/L
—toxic	>10.0	mg/L	4.582	>46	μmol/L	XX	1 μmol/L
procainamide (P)							
—therapeutic	4.0–8.0	mg/L	4.249	17–34	μmol/L	XX	1 μmol/L

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
—toxic	>12.0	mg/L	4.249	>50	μmol/L	XX	1 μmol/L
N-acetylprocainamide (P)							
—therapeutic	4.0–8.0	mg/L	3.606	14–29	μmol/L	XX	1 μmol/L
progesterone (P)							
follicular phase	<2	ng/mL	3.180	<6	nmol/L	XX	2 nmol/L
luteal phase	2–20	ng/mL	3.180	6–64	nmol/L	XX	2 nmol/L
progesterone receptors (T)							
negative	0–3	fmol progesterone bound/mg cytosol protein	1.00	0–3	fmol progesterone bound/mg protein	XX	1 fmol/mg protein
doubtful	4–10	fmol progesterone bound/mg cytosol protein	1.00	4–10	fmol progesterone bound/mg cytosol protein	XX	1 fmol/mg protein
positive	>10	fmol progesterone bound/mg cytosol protein	1.00	>10	fmol progesterone bound/mg cytosol protein	XX	1 fmol/mg protein
prolactin (P)	<20	ng/mL	1.00	<20	μg/L	XX	1 μg/L
propoxyphene (P)—toxic	>2.0	mg/L	2.946	>5.9	μmol/L	X.X	0.1 μmol/L
propranolol (P)							
[Inderal]—therapeutic	50–200	ng/mL	3.856	190–770	nmol/L	XX0	10 nmol/L
protein, total (S)	6.0–8.0	g/dL	10.0	60–80	g/L	XX	1 g/L
protein, total (Sf)	<40	mg/dL	0.01	<0.40	g/L	X.XX	0.01 g/L
protein, total (U)	<150	mg/24 h	0.001	<0.15	g/d	X.XX	0.01 g/d
protryptyline (P)	100–300	ng/mL	3.797	380–1140	nmol/L	XX0	10 nmol/L
pyruvate (B) [as pyruvic acid]	0.30–0.90	mg/dL	113.6	35–100	μmol/L	XXX	1 μmol/L
quinidine (P)							
—therapeutic	1.5–3.0	mg/L	3.082	4.6–9.2	μmol/L	X.X	0.1 μmol/L
—toxic	>6.0	mg/L	3.082	>18.5	μmol/L	X.X	0.1 μmol/L
renin (P)							
normal sodium diet	1.1—4.1	ng/mL/h	0.2778	0.30–1.14	ng/(L · s)	X.XX	0.02 ng/(L · s)
restricted sodium diet	6.2–12.4	ng/mL/h	0.2778	1.72–3.44	ng/(L · s)	X.XX	0.02 ng/(L · s)
salicylate (S) [salicylic acid]—toxic	>20	mg/dL	0.07240	>1.45	mmol/L	X.XX	0.05 mmol/L
serotonin (B) [5-hydroxy-tryptamine]	8–21	μg/dL	0.05675	0.45–1.20	μmol/L	X.XX	0.05 μmol/L
sodium ion (S)	135–147	mEq/L	1.00	135–147	mmol/L	XXX	1 mmol/L
sodium ion (U)	Diet dependent	mEq/24 h	1.00	Diet dependent	mmol/d	XXX	1 mmol/d
steroids							
17-hydroxy-corticosteroids (U) [as cortisol]							
—female	2.0–8.0	mg/24 h	2.759	5–25	μmol/d	XX	1 μmol/d
—male	3.0–10.0	mg/24 h	2.759	10–30	μmol/d	XX	1 μmol/d
17-ketogenic steroids (U) [as dehydroepiandro-sterone]							
—female	7.0–12.0	mg/24 h	3.467	25–40	μmol/d	XX	1 μmol/d
—male	9.0–17.0	mg/24 h	3.467	30–60	μmol/d	XX	1 μmol/d
17-ketosteroids (U) [as dehydroepiandroster-one]							
—female	6.0–17.0	mg/24 h	3.467	20–60	μmol/d	XX	1 μmol/d
—male	6.0–20.0	mg/24 h	3.467	20–70	μmol/d	XX	1 μmol/d
ketosteroid fractions (U)							
androsterone							
—female	0.5–3.0	mg/24 h	3.443	1–10	μmol/d	XX	1 μmol/d
—male	2.0–5.0	mg/24 h	3.443	7–17	μmol/d	XX	1 μmol/d
dehydroepiandrosterone							
—female	0.2–1.8	mg/24 h	3.467	1–6	μmol/d	XX	1 μmol/d

Appendix Table 2 (Continued)

Component	Present reference intervals (examples)	Present unit	Conversion factor	SI reference intervals	SI unit symbol	Significant digits	Suggested minimum increment
—male	0.2–2.0	mg/24 h	3.467	1–7	μmol/d	XX	1 μmol/d
etiocholanolone							
—female	0.8–4.0	mg/24 h	3.443	2–14	μmol/d	XX	1 μmol/d
—male	1.4–5.0	mg/24 h	3.443	4–17	μmol/d	XX	1 μmol/d
sulfonamides (B) [as sulfanilamide]							
—therapeutic	10.0–15.0	mg/dl	58.07	580–870	μmol/L	XX0	10 μmol/L
testosterone (P)							
—female	0.6	ng/mL	3.467	2.0	nmol/L	XX.X	0.5 nmol/L
—male	4.6–8.0	ng/mL	3.467	14.0–28.0	nmol/L	XX.X	0.5 nmol/L
theophylline (P)—therapeutic	10.0–20.0	mg/L	5.550	55–110	μmol/L	XX	1 μmol/L
thiocyanate (P)—							
(nitroprusside toxicity)	10.0	mg/dL	0.1722	1.7	mmol/L	X.XX	0.1 mmol/L
thiopental (P)	individual	mg/L	4.126	individual	μmol/L	XX	5 μmol/L
thyroid tests:							
thyroid stimulating hormone [TSH] (S)	2–11	μU/mL	1.00	2–11	mU/L	XX	1 mU/L
thyroxine [T_4] (S)	4.0–11.0	μg/dL	12.87	51–142	nmol/L	XXX	1 nmol/L
thyroxine binding globulin [TBG] (S)—[as thyroxine]	12.0–28.0	μg/dL	12.87	150–360	nmol/L	XX0	1 nmol/L
thyroxine, free (S)	0.8–2.8	ng/dL	12.87	10–36	pmol/L	XX	1 pmol/L
triiodothyronine [T_3] (S)	75–220	ng/dL	0.01536	1.2–3.4	nmol/L	X.X	0.1 nmol/L
T_3 uptake (S)	25–35	%	0.01	0.25–0.35	1	0.XX	0.01
tolbutamide (P)—therapeutic	50–120	mg/L	3.699	180–450	umol/L	XX0	10 umol/L
transferrin (S)	170–370	mg/dL	0.01	1.70–3.70	g/L	X.XX	0.01 g/L
triglycerides (P) [as triolein]	<160	mg/dL	0.01129	<1.80	mmol/L	X.XX	0.02 mmol/L
trimethadione (P)—therapeutic	<50	mg/L	6.986	<350	μmol/L	XX0	10 μmol/L
trimipramine (P)—therapeutic	50–200	ng/mL	3.397	170–680	nmol/L	XX0	10 nmol/L
urate (S) [as uric acid]	2.0–7.0	mg/dL	59.48	120–420	μmol/L	XX0	10 μmol/L
urate (U) [as uric acid]	Diet dependent	g/24 h	5.948	Diet dependent	mmol/d	XX	1 mmol/d
urea nitrogen (S)	8–18	mg/dL	0.3570	3.0–6.5	mmol/L UREA	X.X	0.5 mmol/L
urea nitrogen (U)	2.0–20.0 diet dependent	g/24 h	35.700	450–700	mmol/d UREA	XX0	10 mol/d
urobilinogen (U)	0.0–4.0	mg/24 h	1.693	0.0–6.8	μmol/d	X.X	0.1 μmol/d
valproic acid (P)							
—therapeutic	50–100	mg/L	6.934	350–700	μmol/L	XX0	10 μmol/L
vanillylmandelic acid [VMA] (U)*	<6.8	mg/24 h	5.046	<35	μmol/d	XX	1 μmol/d
vitamin A [retinol] (P,S)	10–50	μg/dL	0.03491	0.35–1.75	μmol/L	X.XX	0.05 μmol/L
vitamin B_1 [thiamine hydrochloride] (U)	60–500	μg/24 h	0.002965	0.18–1.48	μmol/d	X.XX	0.01 μmol/d
vitamin B_2 [riboflavin] (S)	2.6–3.7	μg/dL	26.57	70–100	nmol/L	XXX	5 nmol/L
vitamin B_6 [pyridoxal] (B)	20–90	ng/mL	5.982	120–540	nmol/L	XXX	5 nmol/L
vitamin B_{12} [cyanocobalamin] (P,S)	200–1000	pg/mL ng/dL	0.7378 7.378	150–750	pmol/L pmol/L	XX0	10 pmol/L
vitamin C [see ascorbate] (B,P,S)	. . .	. . .	. . .	. . .	. . .	. . .	. . .
vitamin D_3 [cholecalciferol] (P)	24–40	μg/mL	2.599	60–105	nmol/L	XXX	5 nmol/L
25 OH-cholecalciferol	18–36	ng/mL	2.496	45–90	nmol/L	XXX	5 mmol/L
vitamin E [alpha-tocopherol] (P,S)	0.78–1.25	mg/dL	23.22	18–29	μmol/L	XX	1 μmol/L
warfarin (P)—therapeutic	1.0–3.0	mg/L	3.243	3.3–9.8	μmol/L	XX.X	0.1 μmol/L
xanthine (U)	5–30	mg/24	6.574	30–200	μmol/d	XX0	10 μmol/d
—hypoxanthine		hmg/24 h	7.347		μmol/d	XX0	10 μmol/d
D-xylose (B) [25 g dose]	30–40 (30–60 min)	mg/dL	0.06661	0–2.7 (30–60 min)	mmol/L	X.X	0.1 mmol/L
D-xylose excretion (U) [25 g dose]	21–31 (excreted in 5 h)	%	0.01	0.21–0.31 (excreted in 5 h)	1	0.XX	0.01
zinc (S)	75–120	μg/dL	0.1530	11.5–18.5	μmol/L	XX.X	0.1 μmol/L
zinc (U)	150–1200	μg/24 h	0.01530	2.3–18.3	μmol/d	XX.X	0.1 μmol/d

* This is a misnomer, but because of its popularity the name VMA has been retained in this document. Elsewhere it is being referred to as 4-hydroxy-3-methoxy mandelic acid.