The use of SI units

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Throughout the United Kingdom SI units are being adopted in line with international practice. The following is a summary of the principles of SI units and outlines the main changes, so that authors may report their findings appropriately.

1 WHAT ARE SI UNITS
(1) SI stands for *Système International* and includes seven base units:

Quantity	Name of SI unit	Symbol for SI unit
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

(2) Derived SI units are obtained by combination of these base units, thus allowing any physical quantity to be expressed in terms of SI units. Some derived SI units have special names and symbols, the more important ones being as follows:

Quantity	Name of SI unit	Symbol for and definition of SI unit
Force	newton	$N = \text{kg} \cdot \text{m} / \text{s}^2$ or $\text{kg} \cdot \text{m} \cdot \text{s}^{-2}$
Pressure	pascal	$\text{Pa} = \text{N} / \text{m}^2$ or $\text{N} \cdot \text{m}^{-2}$
Work, energy, quantity of heat	joule	$J = \text{N} \cdot \text{m}$
Power	watt	$W = \text{J} / \text{s}$ or $\text{J} \cdot \text{s}^{-1}$

(3) The coherent SI unit of volume is the cubic metre but the litre is also recognized as a unit of volume and is exactly equal to one cubic decimeter—i.e. 1000 litre = 1 cubic metre. If any confusion could arise between the symbol for litre (l) and the figure 1, the word litre should be written in full. Concentrations should be expressed with the litre in the denominator:

Mass concentration	kg/l
Amount of substance ('molar') concentration	mol/l

(4) Decimal multiples and submultiples are formed with the following prefixes:

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

(i) The use of prefixes representing 10 raised to a power which is a multiple of 3 is especially recommended. The most widely used ones are kilo, milli, and micro. The symbol for a prefix acts as a convenient shorthand: e.g. 0.000001 g = 10^{-6} g = 1 μ g.

(ii) Compound prefixes should be avoided and only one prefix used in forming decimal multiples or submultiples: e.g. 10^{-9} g is 1 ng *not* 1 m μ g.

A consequence of this rule is that in derived units the prefix should be attached to one unit only, preferably in the numerator; the kilogram is an exception, as kg is the fundamental unit. Thus 1 μ g/ml is better expressed as 1 mg/l.

2 RULES FOR USING UNITS

(1) The symbol for a unit is unaltered in the plural and should not be followed by a full stop except at the end of a sentence: e.g. 5 cm *not* 5 cm. or 5 cms.

(2) The solidus (/) or word 'per' should only be used once in each unit. Where necessary the negative index may be used: e.g. ml/min or ml min^{-1} .

(3) The decimal sign between digits is indicated by a full stop in typing. No commas are used to divide large numbers into groups of three, but a half-space (whole space in typing) is left after every third digit. If the numerical value of the number is less than unity, a zero should precede the decimal sign: e.g. 0.123456 *not* .123456.

(4) When expressing a quantity by a numerical value and a unit, it is in most applications advisable to use a multiple or submultiple which gives a simple whole number between 1 and 999: e.g. 10^{-5} g is best recorded as 10 μ g and *not* 0.01 mg.

(5) The SI symbol for 'day' (i.e. 24 hours) is 'd', but urine and faecal excretions of substance should preferably be expressed as 'per 24 hours' (e.g. g/24 h). Expressions as 'per day' (e.g. g/d) could be interpreted as meaning 'between the hours of sunrise and sunset'.

3 LABORATORY REPORTS

A report of a measurement should always include the unit as well as the numerical value: e.g. plasma cholesterol can be reported as:

$$\text{plasma cholesterol} \left\{ \begin{array}{l} \text{substance concentration} \\ \quad \quad \quad = 3.6 \text{ mmol/l} \\ \text{mass concentration} \\ \quad \quad \quad = 1.4 \text{ g/l} \end{array} \right.$$

To report this result as 'cholesterol = 1.4' is ambiguous.

4 WHAT WILL CHANGE

The main changes involve the units of concentration and pressure. The changes are of four types.

(1) For some tests the unit and symbol will change but the numerical value will be unaltered: e.g. blood platelets = $150000/\text{mm}^3 = 150 \times 10^9/\text{l}$.

(2) For substances of defined chemical composition and known molecular weight, substance (or 'molar') concentration instead of mass concentration will be used. This is obtained by dividing the mass concentration (in grammes per litre) by the molecular weight. In some cases, the analyst refers to an atom, ion, or radical and in these cases the appropriate atomic, ionic, or radical weight is used and the nature of the particle specified. Thus barbiturate, folate, lactate, urate, etc., refer to the ionized radical, not to the acid or base itself.

(3) For substances of undefined composition or molecular weight it is impossible to use molar concentration, and for these mass concentration will continue to be used, but expressed as mass per litre, and not per ml or per 100 ml. This applies to all proteins except haemoglobin (see below, para 5 (1)).

Mass concentration will also be used for expressing plasma vitamin B₁₂ and folate measurements, as the molecular weight of the biologically active compound is uncertain.

(4) The SI unit of pressure is the pascal (symbol Pa), which will eventually replace the very wide range of units of pressure which are currently used. Thus blood gas measurements will be given in the SI

unit (kPa) instead of mmHg. 1 mmHg = 133.32 Pa, 1 kPa = 7.5007 mmHg.

5 WHAT WILL NOT CHANGE?

(1) Haemoglobin: because of uncertainty concerning the elementary entity of haemoglobin that should be used for calculation of molar concentration, it has been agreed that for the time being haemoglobin concentration in blood will be expressed as mass concentration. The convention will be to use g/dl (where dl is the SI symbol for 100 ml) so the numerical values will not change.

(2) At present no change is being made in the units for enzyme assays.

6 CONVERSION TABLES

For most laboratory data the main changes will be in haematology and chemical pathology. Conversion tables are appended and list, in alphabetical order, most of the frequently made measurements, and give some typical values in both SI units and in the units previously used, together with conversion factors and new normal ranges in Leeds. In the tables, the top row of figures are typical values in SI units, and beneath these are given the corresponding values in the present units. The column headed 'particle weight' refers to the atomic, ionic, molecular, or radical weight of the component and is used in deriving the conversion factors. The conversion factor is used as follows: Value in old units $\times$ Factor = Value in SI units or Value in SI units $\div$ Factor = Value in old units. The following abbreviations are used: B = Blood, CSF = Cerebrospinal fluid, F = Faeces, P = Plasma or serum, U = Urine.

7 BIOMECHANICAL DATA

All imperial measurements, such as lb and inch, disappear. Likewise all c.g.s. (centimetre gramme second) units, such as dynes and ergs, go, and many units such as the M.K.S. (metre kilogram second) are also changed.

The following are the SI units used in the expression of biomechanical data.

Mass	kilogram (kg)	1 lb = 0.45359237 kg
Length	metre (m)	1 inch = 0.0254 m
Time	second (s)	
Angle	radian (rad)	1 degree = $\pi/180$ rad
Area	metre ² (m ²)	1 in ² = 645.16 mm ²
Volume	metre ³ (m ³)	1 in ³ = 1.63871 $\times 10^{-5}$ m ³
Velocity	m/s	1 ft/s = 0.3048 m/s
Acceleration	m/s ²	1 ft/s ² = 0.3048 m/s ²
Force = Mass $\times$ Acceleration	Newton (N)	1 lbf = 4.44822 N
Energy, Work = Force $\times$ Distance	Joule (J)	1 ft lbf = 1.35582 J
Power	Watt (W)	1 ft lbf/s = 1.35582 W
Pressure, Stress	Pascal (P) = N/m ²	1 lb/in ² = 6.89476 kPa
Torque	Newton metre (Nm)	1 lbf ft = 1.35582 N $\cdot$ m
Density	kg/m ³	1 lb/ft ³ = 16.0185 kg/m ³
Moment of Inertia	kg $\cdot$ m ²	1 lb ft ² = 0.0421401 kg $\cdot$ m ²
Dynamic Viscosity	Ns/m ² = Pa $\cdot$ s	1 lb s/ft ² = 47.8803 Pa $\cdot$ s
Kinematic Viscosity	m ² /s	1 cStoke = 10 ⁻⁶ m ² /s

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Table

<i>System and Component</i>	<i>Particle weight</i>	<i>Typical results in new units and in old units</i>					<i>To convert from old unit to new unit multiply by</i>	<i>Normal range</i>
B—Acid-base measurements								
pH	—	No change	4.0	5.0	6.0	7.0	9.0	7.35–7.45
PCO ₂	—	3.0	30	38	45	53	68	4.8–5.8 kPa
standard HCO ₃	—	23						22–26 mmol/l
base excess	—	No change						–2 to +2 mmol/l
PO ₂	—	No change						11–15 kPa
	—	8.0	10.0	12.0	14.0	16.0	20.0	
P—Albumin	—	60	75	90	105	120	150	
	—	25	30	35	40	45	50	
U—Albumin	—	2.5	3.0	3.5	4.0	4.5	5.0	
	—	0.2	0.5	1.0	2.0	3.0	4.0	
	—	20	50	100	200	300	400	37–49 g/l
B—Barbiturates:								
Amylobarbitone	226.3	50	100	200	300	400	500	—
Barbitone	184.2	1.1	2.3	4.5	6.8	9.1	11.3	—
	—	50	100	200	300	400	500	—
Phenobarbitone	232.2	0.9	1.8	3.7	5.5	7.4	9.2	—
	—	50	100	200	300	400	500	—
P—Bicarbonate (CO ₂ —CP)	—	1.2	2.3	4.6	6.9	9.3	11.6	—
P—Bilirubin (total)	584.7	No change						21–28 mmol/l
	—	10	20	50	100	200	350	3–15 μ mol/l
P—Caeruloplasmin	—	0.6	1.2	2.9	5.8	11.7	20.5	170–340 mg/l
	—	50	100	200	300	400	600	—
P—Calcium (total)	40.08	5	10	20	30	40	60	2.25–2.60 mmol/l
	—	1.70	2.00	2.30	2.60	2.90	3.20	—
U—Calcium	40.08	6.8	8.0	9.2	10.4	11.6	12.8	Males: 1.25–10.0 mmol/24 h
	—	1.00	3.00	5.00	8.00	10.00	15.00	Females: 1.25–9.0 mmol/24 h
B— β Carotene	536.9	40	120	200	320	400	600	1.9–5.6 μ mol/l
	—	1.0	2.0	4.0	6.0	8.0	10.0	—
U—Catecholamines (as adrenalin)	183.2	54	108	215	323	430	538	0.00546
	—	0.5	1.0	1.5	2.5	5.0	7.5	—
P—Chloride	386.7	92	183	275	458	916	1374	98–107 mmol/l
	—	No change						0.29 yrs: 3.10–6.20 mmol/l
P—Cholesterol	—	2.0	4.0	5.0	6.0	8.0	10.0	30–39 yrs: 3.60–7.00 mmol/l
	—	77	155	193	232	309	387	40–49 yrs: 3.90–8.00 mmol/l
P—Copper	63.54	5.0	8.0	10.0	15.0	20.0	25.0	50–59 yrs: 4.10–8.50 mmol/l
	—	32	51	64	95	127	159	11.0–22.0 μ mol/l
U—Copper	63.54	0.8	1.2	1.6	2.0	5.0	10.0	<1.1 μ mol/24 h
	—	51	76	102	127	318	635	—
U—Coprotoporphyrins	654.7	0.2	0.4	0.6	1.0	2.0	4.0	0.0157
	—	131	261	392	654	1307	2614	0.00153
P—Cortisol	362.5	200	400	600	800	1000	1200	<0.40 μ mol/24 h
	—	7	14	22	29	36	43	—
U—Creatine	131.1	200	300	400	500	600	700	100–600 nmol/l
	—	26	39	52	66	79	105	—
P—Creatinine	113.1	100	200	300	400	600	800	<380 μ mol/24 h
	—	1.1	2.3	3.4	4.5	6.8	9.0	50–140 μ mol/l
U—Creatinine	113.1	5	10	15	20	25	30	Adult males: 13–18 mmol/24 h
	—	0.6	1.1	1.7	2.3	2.8	3.4	Adult females: 7–13 mmol/24 h

F—(Fat as stearic acid)	284	10	20	30	40	60	80	mmol/24 h	3-52	<18 mmol/24 h
P—Fibrinogen	—	2-8 0-5 50	5-7 1-0 100	8-5 2-0 200	11-4 3-0 300	17-0 4-0 400	22-7 5-0 500	g/24 h g/l mg/100 ml	0-01	2-0-4-0 g/l
P—Folate	—	Change in symbol only				400	500	µg/l	—	5-0-21-0 µg/l
CSF—Glucose	180-2	1-0	2-0	3-0	4-0	5-0	8-0	ng/ml	0-0555	0-5-1-1 mmol/l
P—Glucose	180-2	18 1-0 18	36 3-0 54	54 5-0 90	72 8-0 144	90 10-0 180	144 20-0 360	mmol/l mmol/l mg/100 ml	0-0555	less than blood glucose Fasting: 2-5-4-7 mmol/l
B—Haemoglobin	—	Change in symbol only				180	360	g/dl	—	Men: 13-5-18-0 g/dl Women: 11-5-16-5 g/dl 0-5-1-5 g/l
P—Haptoglobins	—	0-2	0-4	0-6	0-8	1-0	1-2	g/100 ml	0-01	<58 µmol/24 h
U—S HIAA	190-2	20 25 4-8	40 50 9-5	60 75 14-2	80 100 19-0	100 125 23-8	120 150 28-5	mg/100 ml µmol/24 h	5-26	<36 µmol/24 h
U—HMMA	198-2	20	50	80	100	120	150	µmol/24 h	5-05	
P—Iron	55-85	4-0 5 28	9-9 10 56	15-8 15 84	19-8 20 112	23-8 30 168	29-7 40 223	mg/24 h µmol/l	0-179	Males: 14-0-31-0 µmol/l Females: 11-0-29-0 µmol/l
P—Iron binding capacity	55-85	10 56	20 112	40 223	60 335	80 447	100 559	µmol/l	0-179	54-0-80-0 µmol/l
B—Lactate	89-07	0-5	1-0	1-5	2-0	3-0	4-0	µg/100 ml	0-112	Fasting: 0-40-1-40 mmol/l
B—Lead	207-2	4-5 1-0 21	8-9 2-0 41	13-4 3-0 62	17-8 4-0 83	26-8 5-0 103	35-7 8-0 166	mg/100 ml µmol/l	0-0483	<1-9 µmol/l
U—Lead	207-2	0-20 41	0-50 103	0-80 166	1-00 207	1-20 248	1-50 310	µmol/24 h µg/24 h	0-00483	<0-40 µmol/24 h
B—Leucocytes	—	4-0 4 000	8-0 8 000	12-0 12 000	16-0 16 000	20-0 20 000	310	per mm ³	10 ⁶	4-0-11-0 × 10 ⁹ /l
P—Magnesium	24-31	0-2 0-5	0-4 1-0	0-6 1-5	0-8 1-9	1-0 2-4	1-5 3-6	mmol/l	0-411	0-7-1-0 mmol/l
U—Magnesium	24-31	1-0 24	2-0 49	3-0 73	4-0 97	5-0 122	8-0 195	mmol/24 h mg/24 h	0-0411	3-0-6-0 mmol/24 h
B—Mean Corpuscular Haemoglobin (MCH)	—	No change				122	195	pg	—	27-34 pg
B—Mean Corpuscular Haemoglobin Concentration (MCHC)	—	Change in symbol only				122	195	g/dl	—	30-35 g/dl
B—Mean Corpuscular Volume (MCV)	—	Change in symbol only				122	195	%	—	30-35 g/dl
U—Oestriol	288-4	20	30	50	70	90	120	µm ³	—	Pregnancy rising to >70 µmol/24 h
U—17 oxogenic steroids	288-4	5-8 20	8-6 40	14-4 60	20-2 80	25-9 100	34-6 150	µmol/24 h	3-47	Adult male: 30-60 µmol/24 h
U—17 oxosteroids	288-4	5-8 20	11-5 40	17-3 60	23-1 80	28-8 100	43-2 150	mg/24 h	3-47	Adult female: 20-60 µmol/24 h
B—Packed cell volume (PCV)	—	5-8 0-25 25	11-5 0-30 30	17-3 0-35 35	23-1 0-40 40	28-8 0-45 45	43-2 0-50 50	mg/24 h	0-01	Adult male: 30-70 µmol/24 h Adult female: 20-60 µmol/24 h Men: 0-40-0-50 Women: 0-35-0-47
B—Platelets	—	100 000 100	200 000 200	400 000 400	600 000 600	800 000 800 000	10 ⁶	% per mm ³	10 ⁶	150-400 × 10 ⁹ /l

Table—continued

System and Component	Particle weight	Typical results in new units and in old units					To convert from old unit to new unit multiply by		Normal range
B—Phenylalanine	165.2	0.1	0.2	0.3	0.4	0.6	mmol/l	0.0605	0.03–0.12 mmol/l
P—Phosphorus (inorganic)	30.97	1.6	3.3	5.0	6.6	9.9	mg/100 ml	0.323	0.8–1.3 mmol/l
P—Potassium	—	0.5	1.0	1.5	2.0	3.0	mmol/l	—	3.6–5.0 mmol/l
U—Pregnanediol	320.5	1.5	3.1	4.6	6.2	7.7	mg/100 ml	—	At term: $\geq 70 \mu\text{mol}/24 \text{ h}$
U—Pregnanetriol	336.5	No change	4.0	7.0	10.0	15.0	mmol/l	3.12	Adults: 3–9 $\mu\text{mol}/24 \text{ h}$
P—Protein (total)	—	0.6	1.3	2.2	3.2	4.8	mg/24 h	2.97	67–82 g/l
CSF—Protein	—	2.0	4.0	5.0	6.0	7.0	$\mu\text{mol}/24 \text{ h}$	10.0	0.20–0.40 g/l
U—Protein	—	0.7	1.3	2.4	3.4	5.0	mg/24 h	0.01	—
P—PBI	126.9	30	40	50	60	70	g/l	0.01	—
B—Pyruvate	87.05	3.0	4.0	5.0	6.0	8.0	g/100 ml	78.8	300–620 nmol/l
B—Red Cell Count (RCC)	—	0.2	0.4	0.6	0.8	1.0	g/l	115	10–110 $\mu\text{mol}/\text{l}$
B—Reticulocytes	—	20	40	60	80	100	mg/100 ml	—	Men: $5\text{--}6.5 \times 10^{12}/\text{l}$
P—Salicylate	137.1	0.5	1.0	1.5	2.0	3.0	%	—	Women: $3\text{--}9\text{--}5.6 \times 10^{12}/\text{l}$
P—Sodium	—	7	14	21	27	41	mmol/l	0.0729	0.2–2.0%
P—Triglyceride (as triolein)	885.5	No change	0.7	1.0	1.5	2.0	mmol/l	—	135–145 mmol/l
P—Urate	167.1	0.4	0.7	1.0	1.5	2.0	mmol/l	0.0113	$< 1.70 \text{ mmol}/\text{l}$
P—Urea	60.06	35	62	88	133	177	mg/100 ml	0.0598	Male: 0.20–0.45 mmol/l
U—Urea	60.06	1.0	2.0	3.0	4.0	5.0	mmol/l	0.166	Female: 0.14–0.38 mmol/l
P—Vitamin A	286.4	1.7	3.3	5.0	6.7	8.4	mg/100 ml	166	2.5–7.1 mmol/l
P—Vitamin B ₁₂ (as cyanocobalamin)	—	3.0	6.0	8.0	10.0	15.0	mmol/l	—	170–580 mmol/l
P—Xylose	150.1	18	36	48	60	90	mg/100 ml	0.0349	1.7–4.5 $\mu\text{mol}/\text{l}$
		50	100	150	250	350	g/100 ml	—	160–925 ng/l
		0.3	0.6	0.9	1.5	2.1	ng/ml	0.0667	—
		0.5	1.0	2.0	3.0	4.0	mmol/l	—	—
		14	29	57	86	115	mg/100 ml	—	—
		Change in symbol only							
		0.5	1.0	2.0	3.0	4.0	mg/100 ml	—	—
		7.5	15	30	45	60	mmol/l	—	—