Constants and Units

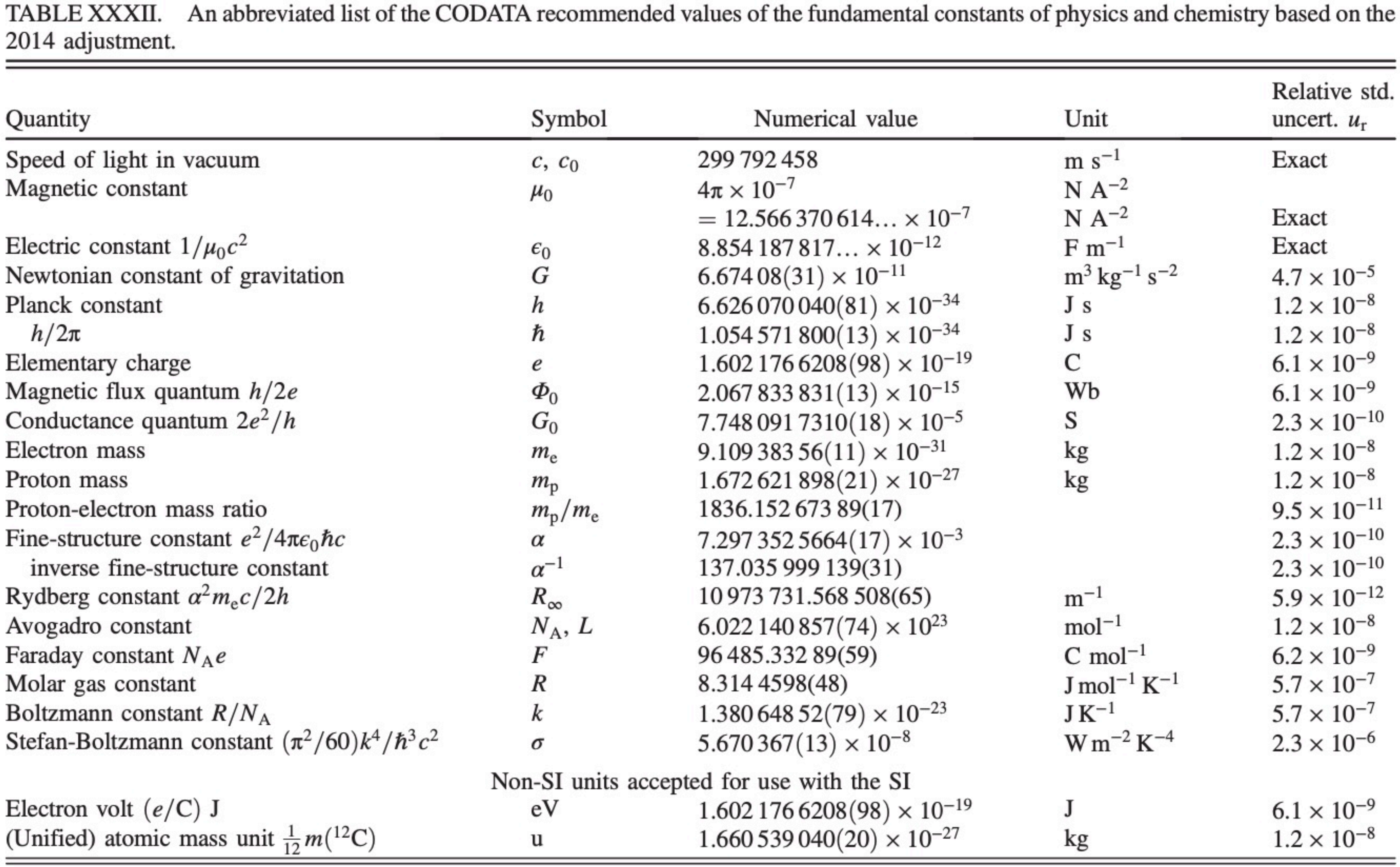


TABLE XXXII. An abbreviated list of the CODATA recommended values of the fundamental constants of physics and chemistry based on the 2014 adjustment.

Quantity	Symbol	Numerical value	Unit	Relative std. uncert. u_r
Speed of light in vacuum	c, c_0	299 792 458	$\mathrm{m\ s^{-1}}$	Exact
Magnetic constant	μ_0	$4\pi \times 10^{-7}$	$\mathrm{N\ A^{-2}}$	
		$= 12.566\,370\,614\ldots \times 10^{-7}$	$\mathrm{N\ A^{-2}}$	Exact
Electric constant $1/\mu_0 c^2$	ϵ_0	$8.854\,187\,817\ldots \times 10^{-12}$	$\mathrm{F\ m^{-1}}$	Exact
Newtonian constant of gravitation	G	$6.674\,08(31) \times 10^{-11}$	$\mathrm{m^3\ kg^{-1}\ s^{-2}}$	4.7×10^{-5}
Planck constant	h	$6.626\,070\,040(81) \times 10^{-34}$	J s	1.2×10^{-8}
$h/2\pi$	$\hbar$	$1.054\,571\,800(13) \times 10^{-34}$	J s	1.2×10^{-8}
Elementary charge	e	$1.602\,176\,6208(98) \times 10^{-19}$	C	6.1×10^{-9}
Magnetic flux quantum $h/2e$	Φ_0	$2.067\,833\,831(13) \times 10^{-15}$	Wb	6.1×10^{-9}
Conductance quantum $2e^2/h$	G_0	$7.748\,091\,7310(18) \times 10^{-5}$	S	2.3×10^{-10}
Electron mass	m_e	$9.109\,383\,56(11) \times 10^{-31}$	kg	1.2×10^{-8}
Proton mass	m_p	$1.672\,621\,898(21) \times 10^{-27}$	kg	1.2×10^{-8}
Proton-electron mass ratio	m_p/m_e	1836.152 673 89(17)		9.5×10^{-11}
Fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	α	$7.297\,352\,5664(17) \times 10^{-3}$		2.3×10^{-10}
inverse fine-structure constant	α^{-1}	137.035 999 139(31)		2.3×10^{-10}
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 508(65)	$\mathrm{m^{-1}}$	5.9×10^{-12}
Avogadro constant	N_A, L	$6.022\,140\,857(74) \times 10^{23}$	$\mathrm{mol^{-1}}$	1.2×10^{-8}
Faraday constant $N_A e$	F	96 485.332 89(59)	$\mathrm{C\ mol^{-1}}$	6.2×10^{-9}
Molar gas constant	R	8.314 4598(48)	$\mathrm{J\ mol^{-1}\ K^{-1}}$	5.7×10^{-7}
Boltzmann constant R/N_A	k	$1.380\,648\,52(79) \times 10^{-23}$	$\mathrm{J\ K^{-1}}$	5.7×10^{-7}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3 c^2$	σ	$5.670\,367(13) \times 10^{-8}$	$\mathrm{W\ m^{-2}\ K^{-4}}$	2.3×10^{-6}
Non-SI units accepted for use with the SI				
Electron volt (e/C) J	eV	$1.602\,176\,6208(98) \times 10^{-19}$	J	6.1×10^{-9}
(Unified) atomic mass unit $\frac{1}{12}m(^{12}\mathrm{C})$	u	$1.660\,539\,040(20) \times 10^{-27}$	kg	1.2×10^{-8}

Fourier Transforms

$$F(u) = \frac{1}{2\pi}\int f(x)\cdot e^{-i\cdot 2\pi\cdot u\cdot x}\,dx$$

$$FT(rect(ax)) = \frac{1}{|a|} sinc\left(\frac{u}{a}\right)$$

The Fourier transform of a rectangular function is the sinc function.

$$FT(sinc(ax)) = \frac{1}{|a|} rect\left(\frac{u}{a}\right)$$

The Fourier transform of a sinc function is a rectangular function.

$$FT(e^{-ax^2}) = \sqrt{\frac{\pi}{a}}\cdot e^{-\frac{(\pi u)^2}{a}}$$

The Fourier transform of a Gaussian function
is a Gaussian function.

$$FT(\delta(x)) = 1$$

The Fourier transform of a delta function is a constant.

$$FT(1) = \delta(u)$$

The Fourier transform of a constant function is a delta function.

Fourier Equations

$$FT(a \cdot f(x)) = a \cdot F(u)$$

If you put more contrast in the image, then the FFT's amplitude gets stronger.

$$FT(f(x) + g(x)) = F(u) + G(u)$$

Adding two images f and g and calculating their FFT
is like adding the FFTs F and G of them.

$$FT(f(ax)) = F(u/a)$$

If you stretch an image by a,
then you shorten the FFT by a.
(===> reciprocity)

$$FT(\mathit{rotated}\ \ f(x)) = \mathit{rotated}\ \ F(u)$$

If you rotate and image,
then you also rotate its FFT.

$$f(x) \otimes g(x) = FT^{-1}\left[F(u) \cdot G(u)\right]$$

Convolution.

$$f(x) \times g(x) = FT^{-1}\left[F(u) \cdot G^{*}(u)\right]$$

Cross-Correlation.

ATP Energy

PMF := 2.3 RT ΔpH + F $\Delta\Psi$

R = Gas Constant = 8.315 J/mol/K
T = Temperature (= 300 Kelvins at room temperature)
F = Faraday Constant = 96.5 kJ/V/mol
$\Delta\Psi =$ electrical membrane potential = 200 mV

How much energy does the hydrolysis of ATP produce?

ATP-Energy = ΔG(ATP → ADP+P_i)

$$\Delta G = \Delta G^0 + RT\ln\frac{[\mathrm{ADP}][\mathrm{P_i}]}{[\mathrm{ATP}]}$$

Typically: [ADP]=0.25 mM, [P_i]=2.0 mM, [ATP]=2.5 mM

$$\Delta G = \Delta G^0 + RT\ln\left(\frac{0.25\cdot10^{-3}\cdot2.0\cdot10^{-3}}{2.5\cdot10^{-3}}\right)$$

$$\Delta G = \Delta G^0 + RT\ln(0.0002)$$

Therefore:

ΔG = -30.5 kJ/mol - 21.2 kJ/mol = -51.7 kJ/mol

Chromatographic Distribution

Which fraction of the material would be present after n transfers in tube r ?

$$f(r) = \binom{n}{r} * p^{n-r} * q^{r}$$

n is number of transfers
r is number of tube

$$"n \ \ over \ \ r" = \binom{n}{r} = \frac{n!}{(n-r)! \ * \ \ r!}$$

If n is large, then $\binom{n}{r}$ becomes a normal distribution:

$$f(r) = \frac{1}{\sqrt{2\pi npq}} * e^{-\frac{(r-nq)^2}{2npq}}$$

$$Variance = npq = \sigma^2$$

Basics of Electricity

Speed of particle in an electric field

$$\boxed{v = \frac{E \cdot q}{f}}$$

v = speed of particle [m/s]

E = electric field strength [V/m]

q = charge of particle [$\mathrm{C} = 6.241 \cdot 10^{18} e$]

f = frictional coefficient [$\mathrm{V} \cdot \mathrm{C} \cdot \mathrm{s/m^2}$]

Electric Power of a Current

$$W = U \cdot I$$

$$\boxed{W = I^2 \cdot R}$$

W = electric power [Watt]

I = electric current [Ampere]

R = electric resistance [Ohm]

Electric field strength

$$\boxed{E = \frac{U}{d}}$$

E = electric field strength [Volt/meter]

U = electric potential difference [Volt]

d = distance [meter]

Electrophoretic Mobility

$$\boxed{R_f = \frac{v}{E}}$$

R_f = electric mobility [$1/(\mathrm{V} \cdot \mathrm{s})$]

(also called μ)

v = speed of particle [m/s]

E = electric field strength [Volt/meter]

Ohm’s law

$$\boxed{U = R \cdot I}$$

U = electric potential difference [Volt]

R = resistance [Ohm]

I = electric current [Ampere = C/s]

Electrophoretic Mobility

$$\boxed{R_f = \frac{q}{f}}$$

R_f = electric mobility [$1/(\mathrm{V} \cdot \mathrm{s})$]

(also called μ)

q = charge of particle [C]

f = frictional coefficient [$\mathrm{V} \cdot \mathrm{C} \cdot \mathrm{s/m^2}$]

Mass Spectrometry

m = Mass of the particle
q = Charge of the particle
v = Velocity of the particle
t = time
d = distance
B = Magnetic Field
E = Electric Field
U = Electric Voltage (the value of **E**)

$$d = v \cdot t$$

Magnetic Spectrometer:

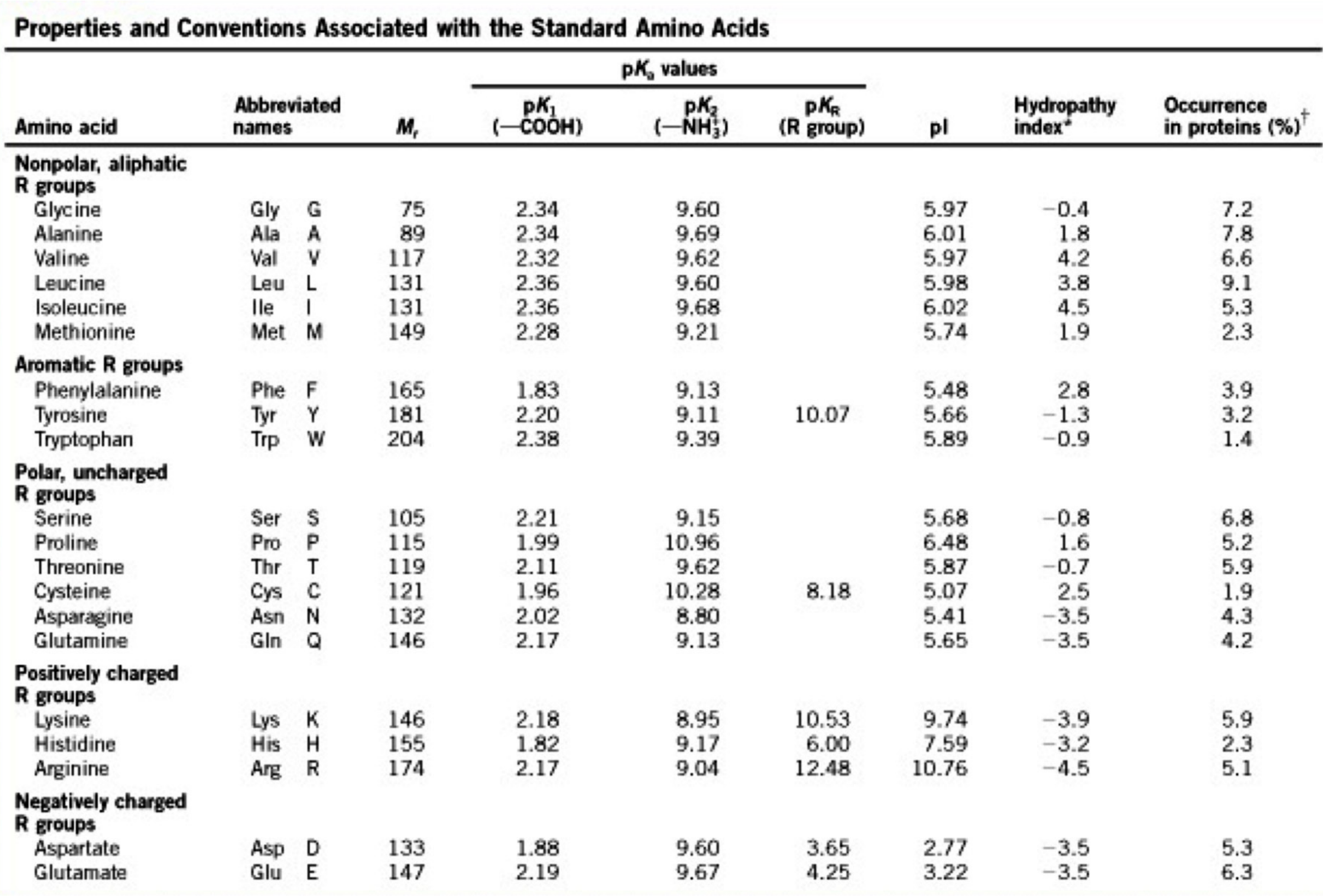
$$\text{"acceleration into curve"} = B \times v$$

Time-of-Flight Measurement:

Energy of an accelerated particle:

$$q \cdot U = \frac{1}{2} \cdot m \cdot v^2$$

$$\frac{m}{q} = 2 \cdot \frac{U}{v^2} = 2 \cdot U \cdot \frac{t^2}{d^2}$$



Properties and Conventions Associated with the Standard Amino Acids

Amino acid	Abbreviated names		M_r	pK_a values pK_1 (—COOH)	 pK_2 (—NH_3^+)	 pK_R (R group)	pI	Hydropathy index*	Occurrence in proteins (%)[†]
Nonpolar, aliphatic R groups									
Glycine	Gly	G	75	2.34	9.60		5.97	−0.4	7.2
Alanine	Ala	A	89	2.34	9.69		6.01	1.8	7.8
Valine	Val	V	117	2.32	9.62		5.97	4.2	6.6
Leucine	Leu	L	131	2.36	9.60		5.98	3.8	9.1
Isoleucine	Ile	I	131	2.36	9.68		6.02	4.5	5.3
Methionine	Met	M	149	2.28	9.21		5.74	1.9	2.3
Aromatic R groups									
Phenylalanine	Phe	F	165	1.83	9.13		5.48	2.8	3.9
Tyrosine	Tyr	Y	181	2.20	9.11	10.07	5.66	−1.3	3.2
Tryptophan	Trp	W	204	2.38	9.39		5.89	−0.9	1.4
Polar, uncharged R groups									
Serine	Ser	S	105	2.21	9.15		5.68	−0.8	6.8
Proline	Pro	P	115	1.99	10.96		6.48	1.6	5.2
Threonine	Thr	T	119	2.11	9.62		5.87	−0.7	5.9
Cysteine	Cys	C	121	1.96	10.28	8.18	5.07	2.5	1.9
Asparagine	Asn	N	132	2.02	8.80		5.41	−3.5	4.3
Glutamine	Gln	Q	146	2.17	9.13		5.65	−3.5	4.2
Positively charged R groups									
Lysine	Lys	K	146	2.18	8.95	10.53	9.74	−3.9	5.9
Histidine	His	H	155	1.82	9.17	6.00	7.59	−3.2	2.3
Arginine	Arg	R	174	2.17	9.04	12.48	10.76	−4.5	5.1
Negatively charged R groups									
Aspartate	Asp	D	133	1.88	9.60	3.65	2.77	−3.5	5.3
Glutamate	Glu	E	147	2.19	9.67	4.25	3.22	−3.5	6.3