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Radiation Laboratory

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PHYSICAL CONSTANTS

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Berkeley, California

PHYSICAL CONSTANTS.

A. Distances (in cm)

SYMBOL	FORMULA	MEANING	VALUE
r_0	e^2/mc^2	clas. radius of elect.	2.8183×10^{-13}
$\lambda\!\!\!^{-}_0$	$\hbar/mc$	Compton wavelength	3.8619×10^{-11}
a_0	$\hbar^2/mc^2$	first Bohr radius	5.2920×10^{-9}
$d_{20°}$	-----	calcite grating space, 20°C	3.0357×10^{-8}
--	-----	internuclear distance in H_2^1	0.7414×10^{-8}

Table of wavelengths for various energies.
For the electron, proton, and neutron $\lambda\!\!\!^{-} = \hbar/P$ is given, while for the photon λ itself is given.

E	$kT_{20°}$	1 ev	1 Mev
Electron	12.280×10^{-8}	1.9518×10^{-8}	$1.3875_ \times 10^{-11}$
Proton	$.28655_ \times 10^{-8}$	$.045543 \times 10^{-8}$	4.5531×10^{-13}
Neutron	$.28635_+ \times 10^{-8}$	$.045512 \times 10^{-8}$	4.5501×10^{-13}
Photon	.0049068	$12{,}395._+ \times 10^{-8}$	$.012395 \times 10^{-8}$

B. Velocities (in cm/sec)

	V	$\beta = v/c$
C = velocity of light in vacuo	2.99776×10^{10}	1
$V_0 = e^2/\hbar$ = velocity of electron in first Bohr orbit	2.1877×10^8	.0072977
Velocity of electron with energy of $kT_{20°}$	9.4277×10^6	.00031449
1 ev	5.9317×10^7	.0019787
1 Mev	2.8212×10^{10}	.94110

	v	$\beta = v/c$
Velocity of proton with energy of $kT_{20°}$	2.1999×10^5	7.3384×10^{-6}
1 ev	1.3841×10^6	4.6172×10^{-5}
1 Mev	1.3830×10^9	.046135_
Initial velocity of a RaC' alpha particle	1.9215×10^9	.064098

C. Dimension-less Constants

α = fine-structure constant = $e^2/\hbar c$ = .0072977 = 1/137.030

$M_{p/m}$ = ratio of masses of proton and electron = 1836.5_5-

D. Energy and Mass.

Energy of repulsion of two electrons one cm. apart = 1.4397×10^{-7} ev.

$kT_{0°C}$ = 0.02354 ev = 3.771×10^{-14} erg
$kT_{15°C}$ = 0.02483 ev = 3.978×10^{-14} erg
$kT_{20°C}$ = 0.02526 ev = 4.047×10^{-14} erg

(electron volts are absolute)

mc^2 = rest energy of electron = 0.51083 Mev = 8.1837×10^{-7} erg

$E_0 = me^4/\hbar^2 = e^2/a_0 = mc^2 \times \alpha^2$ = potential energy of first Bohr orbit = 27.205_ ev = 4.3583×10^{-11} erg.

I_H = Ionization potential of H' =

$$\frac{1}{2} E_0(1+\alpha^2/4)(1+m/M_p)-1 = 13.595 \text{ ev}$$

Energy of first vibrational quantum of H_2' = 0.5150 ev.

Energy of first rotational quantum of H_2' = 0.01471 ev

Energy of dissociation of H_2' = 4.4776 ev

Initial energy of a RaC' alpha particle = 7.6802 Mev

	Mass (gm)	At. wt (physical)	Rest energy (Mev)	Mass/m
Electron	9.1066×10^{-28}	0.00054862	0.51083	1
Proton	1.67247×10^{-24}	1.00757	938.17	1836.5
H Atom	1.67338×10^{-24}	1.00812	938.68	1837.5
Neutron	1.67472×10^{-24}	1.00893	939.43	1839.0
Deuteron	3.34330×10^{-24}	2.01416	1875.41	3671.3
Alpha particle	6.64424×10^{-24}	4.00280	3727.07	7296.1
Unit Mass	1.65990×10^{-24}	1	931.12	1822.7
Chemical mass	1.66035×10^{-24}	1.00072	931.37	1823.2

E. Energy Conversion Factors

	abs ev	ergs	cm^{-1}	cal (15°)	cal/mde
1 ev =	1	1.60203×10^{-12}	806749	3.8276×10^{-20}	23,052.8
1 erg =	6.2421×10^{11}	1	5.035×10^{15}	2.3892×10^{-8}	1.4390×10^{16}
1 cm =	1.2395×10^{-4}	1.9858×10^{16}	1	4.7444×10^{-24}	2.8575
1 cal (15°) =	2.6126×10^{19}	4.1855×10^{7}	2.107×10^{23}	1	6.0228×10^{23}
1 erg/mole =	1.0364×10^{-12}	1.6603×10^{-24}	8.3612×10^{-9}	3.9669×10^{-32}	2.3892×10^{-8}
1 cal/mole =	4.3379×10^{-5}	6.9494×10^{-17}	0.34996	1.6603×10^{-24}	1

F. Miscellaneous

e = charge of electron = 4.8025×10^{-10} abs esu
= 1.60203×10^{-20} abs emu.

$e^2 = 1.4397 \times 10^{-7}$ abs ev cm = 2.3064×10^{-19} (abs esu)^2 = 2.56650×10^{-40} (abs emu)^2

$e^4 = 5.31948 \times 10^{-38}$ (abs esu)^4

e/m = "specific" electron charge = 1.7592×10^7 emu/gm = 5.2737×10^{17} esu/gm

$e/h = 7.2499 \times 10^{16}$ esu/erg sec = 2.4185×10^6 emu/erg sec.

h = Planck's constant = $6.624_2 \times 10^{-27}$ erg·sec
= $4.134_9 \times 10^{-15}$ ev sec.

$\hbar = h/2\pi = 1.0543 \times 10^{-27}$ erg sec = $6.580_8 \times 10^{-16}$ ev sec.

$\pi = 3.1415927$, $2\pi = 6.2831853$

$\pi^2 = 9.8696044$, $2\pi^2 = 19.7392088$

$4\pi = 12.5663706$, $4\pi^2 = 39.4784176$

$1/\pi = 0.3183099$, $1/2\pi = 0.1591549$
$1/4\pi = 0.0795775$

$\pi/2 = 1.5707963$, $\pi/4 = 0.7853982$

$\epsilon = 2.71828\ 18285$

$\mathrm{Log}_\epsilon 10 = 2.30258509$

$hc = 1.23954 \times 10^{-4}$ ev cm = 1.98578×10^{-16} erg cm

$\hbar/m = 1.1577$ erg sec/gm.

T_0 = Temperature of "absolute zero" = $-273.16°C$

A_0 = Pressure of standand atmosphere
= 1.0132×10^6 dynes/cm^2

F = Faraday constant = 96,501 Coulombs per gram equivalent.

R = Gas constant = 8.31436 joules/mole degree
= 1.98647 cal/mole deg.
= 8.20545×10^{-2} liter atm/mole degree

K = Boltzmann constant = 1.38047×10^{-16} erg/deg = 3.2982×10^{-24} cal/deg
= 8.6170×10^{-5} ev/deg.

k/h = 2.0840×10^{10} /deg sec.

k/hc = 0.69518/deg cm

hc/k = 1.4385 deg cm = second radiation constant.

μ = Bohr (atomic) magneton = $e\hbar/2mc$ = 9.273×10^{-21} erg/gauss

μ_n = Bohr (nuclear) magneton = $e\hbar/2M_pC$ = 5.049×10^{-24} erg/gauss

G = Gravitational constant = 6.670×10^{-8} dyne cm/gram^2

g_0 = Acceleration due to gravity (stand.) = 980.665 cm/sec^2

G. Number of Molecules

		NO	LOG_{10}
No	Avogadro's no.; 1 mole	6.0228×10^{23}	23.77980
no	Loschmidt's no; 1cc of ideal gas at 0°C, 1atm	2.6870×10^{19}	19.42927
--	1cc of ideal gas at 15°C, 1atm	2.5471×10^{19}	19.40605
--	1cc of ideal gas at 20°C, 1atm	2.5037×10^{19}	19.39858
--	1cc of dry air (MW = 28.96_7) at 15°C, 1atm	2.5483×10^{19}	19.40625

H. Volumes

Vol. of 1 mole ideal gas, 0° C, 1 atm = 22,414.6 cc
" " " " " " 15° C, 1 atm = 23 645 "
" " " " " " 20° C, 1 atm = 24,056 "
" " " " dry air, 15° C, 1 atm = 23,635 "

I. Time (in seconds)

τ_0 = period of first Bohr orbit = $2\pi a_0/v_0$
$= 2\pi\hbar^3/me^4 = 1.5198 \times 10^{-16}$

t_0 = time required for light to move a distance of one classical electron radius = $e^2/mc^3 = 9.4013 \times 10^{-24}$

J. Frequencies (in reciprocal seconds)

$1/\tau_0 = me^4/2\pi\hbar^3 = 6.5798 \times 10^{15}$

$R_\infty C = me^4/4\pi\hbar^3 = 3.28988 \times 10^{15}$

K. Wave Numbers (in reciprocal cm)

S_0 = wave no. of photon of 1ev energy
= 8067.5

$kT_{20°}/hc$ = wave no. of photon at thermal energy = 203.80

R_H = Rydberg constant for H^1 = 109,677.581
R_D = " " " H^2 = 109,707.419
R_{He} = " " " He^4 = 109,722.263
R_∞ = " " " infinite mass
= 109,737.303

L. Some Fundamental Quantities Expressed in Various Systems of Units.

		C.G.S.	Electron	Atomic (Hartree)
Mass	Mass of Electron	m	1	1
	Mass of Proton	M_p	1836.5	1836.5
Length	Radius of Electron	$e^2/mc^2 = r_0$	1	$1/137^2$
	Radius of H Atom	$\hbar^2/me^2 = a_0$	137^2	1
	Compton wavelength	$\hbar^2/mc = \lambda\!\!\!^{-}_0$	137	1/137
Time	Time required for light to pass r_0	$e^2/mc^3 = t_0$	1	$1/137^3$
	Period of first Bohr orbit 2π	$\hbar^3/me^4 = \tau_0$	$137^3 2\pi$	2π
Energy	Rest energy of electron	mc^2	1	137^2
	Potential energy of H Atom	$me^4/\hbar^2 = E_0$	$1/137^2$	1
Velocity	Velocity of light	c	1	137
	Velocity of Is II electron	$e^2/\hbar = v_0$	1/137	1
Frequency	$1/t_0$	mc^3/e^2	1	137^3
	$1/\tau_0$	$me^4/2\pi\hbar^3$	$1/137^3 2\pi$	$1/2\pi$
Angular Momentum	-----	e^2/c	1	1/137
	Planck's constant	$\hbar$	137	1
Electric Charge	Charge of electron	e	1	1
Momentum		mc	1	137
		$me^2/\hbar$	1/137	1

From Bigeleisen, MDDC-273