Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988$ GNm^2/C^2 (Coulomb's Law)

$e = 1.602 \times 10^{-19}$ C (proton charge)

$m_e = 9.109 \times 10^{-31}$ kg (electron mass)

$c = 3.00 \times 10^{8}$ m/s (speed of light)

$h = 6.62607 \times 10^{-34}$ J·s (Planck's constant)

$\sigma = 5.67 \times 10^{-8}$ W/(m^2·K^4) (Stefan-Boltzmann const.)

$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)

$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)

$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

$c = 2.99792458 \times 10^{8}$ m/s (exact value in vacuum)

$\hbar = 1.05457 \times 10^{-34}$ J·s (Planck's constant/2π)

hc =1239.84 eV·nm (photon energy constant)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)

1.0 eV = 1.602×10^{-19} J (electron-volt)

1 F = 1 C/V = 1 farad = 1 C^2/J

1 A = 1 C/s = 1 ampere = 1 coulomb/second

1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter

1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)

1 V = 1 J/C = 1 volt = 1 joule/coulomb

1 H = 1 V·s/A = 1 henry = 1 J/A^2

1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2

1 G = 10^{-4} T = 1 gauss = 10^{-4} tesla

OpenStax Chapter 24 Equations - Electromagnetic Waves

Electromagnetic waves:

$|\vec{E}|/|\vec{B}| = c = 1/\sqrt{\epsilon_0\mu_0}$, (fields and speed)

$f\lambda = c$ (wave equation)

Energy density, intensity, power:

$u = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$ (instantaneous energy density)

$\overline{u} = \frac{1}{2}\epsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0}$ (average energy density)

$I = \overline{u}c = \frac{1}{2}\epsilon_0 E_0^2 c$ (EM waves intensity)

$I = P/A = P/(4\pi r^2)$ (intensity definition)

Approximate wavelengths λ for types of EM waves:

0 (γ-rays) 30 pm (x-rays) 3 nm (uv) 400 nm (visible) 700 nm (ir) 300 μm (μ-waves) 3 cm (radio) ∞

$\longrightarrow$ $\longrightarrow$ $\longrightarrow$ increasing wavelength $\longrightarrow$ $\longrightarrow$ $\longrightarrow$

OpenStax Chapter 28 Equations - Special Relativity

Time dilation and length contraction:

$\Delta t = \gamma\Delta t_0 = \Delta t_0/\sqrt{1 - v^2/c^2}$

$\gamma = 1/\sqrt{1 - v^2/c^2}$ (relativistic factor)

$L = L_0/\gamma = L_0\sqrt{1 - v^2/c^2}$

$v/c = \sqrt{1 - 1/\gamma^2}$ (velocity)

Dyanmics, mass, energy:

$p = \gamma m v$ (relativistic momentum)

$E_0 = mc^2$ (rest energy)

$\mathrm{KE} = E - E_0 = (\gamma - 1)mc^2$ (kinetic energy)

$\Delta(E_0 + \mathrm{KE}) + \Delta\mathrm{PE} = 0$ (conservation of energy)

$m_{\mathrm{rel}} = \gamma m$ (relativistic mass)

$E = \gamma mc^2 = m_{\mathrm{rel}}c^2$ (relativistic energy)

$E = E_0 + \mathrm{KE} = \sqrt{p^2c^2 + m^2c^4}$ (relativistic energy)

$\Delta\mathrm{PE}_{\mathrm{elec}} = q\Delta V$ (electric potential energy)

OpenStax Chapter 29 Equations - Quanta and Quantum Waves

Blackbody radiation, photons, photo-electric effect:

$\lambda_p T = 2.90$ mm·K (Wien's Law)

$I = \sigma T^4$ (intensity or power/area)

$E = nhf,\ n = 1, 2, 3...$ (quantized radiation energy)

$E = hc/\lambda = (1240 \text{ eV} \cdot \text{nm})/\lambda$ (photons)

$E = hf = W_0 + \text{KE}_{\text{max}}$ (photo-electrons)

$hc/\lambda_{\text{max}} = W_0$ (work function)

$\text{KE}_{\text{max}} = eV_0$ (stopping potential)

$v_{\text{max}} = \sqrt{2\text{KE}_{\text{max}}/m}$ (max. speed)

Momentum, matter waves:

$p = h/\lambda$ (quantum momentum)

$\lambda' = \lambda + \frac{h}{mc}(1 - \cos\phi)$ (Compton effect)

$\lambda = h/p$ (de Broglie wavelength)

KE$= p^2/2m$ (kinetic energy, $v \ll c$)

$\Delta\text{KE} + q\Delta V = 0$ (acceleration thru potential)

$v = \sqrt{2q\Delta V/m}$ (acceleration thru potential, $v \ll c$)

Heisenberg Uncertainty Principle:

$\Delta x\ \Delta p_x \approx h$ (approximate relation)

$h = 6.626 \times 10^{-34}$ J·s

$\Delta E\ \Delta t \approx h$ (approximate relation)

$\Delta x\ \Delta p_x \geq \hbar/2$ (has the minimum uncertainty)

$\hbar = \frac{h}{2\pi} = 1.05459 \times 10^{-34}$ J·s

$\Delta E\ \Delta t \geq \hbar/2$ (energy-time form)

$\Delta E = \Delta m \cdot c^2$ (Einstein's mass-energy equivalence)

← This has exact equality.

OpenStax Chapter 30 Equations - Atomic Physics

Bohr Model:

$hf = E_n - E_{n'}$ (quantum jump)

$L = mvr = n\frac{h}{2\pi}$ (Bohr's quantization)

$r_n = \frac{n^2}{Z} r_1$ (Bohr radii)

$r_1 = \frac{h^2}{4\pi^2 mke^2} = 52.9$ pm (1^{st} Bohr radius)

$E_n = -(13.6 \text{ eV})\frac{Z^2}{n^2}$ (Bohr energies)

$E_n = \frac{1}{2}mv^2 - \frac{kZe^2}{r_n}$ (total energy)

$n = 1, 2, 3, ...$ (Bohr's quantum number)

$E = hc/\lambda = (1240 \text{ eV} \cdot \text{nm})/\lambda$ (photons)

Quantum numbers for atoms:

principle quantum number $n = 0, 1, 2, 3...$

$E_n = -(13.6 \text{ eV})/n^2$ (energy of hydrogen states)

orbital quantum number $l = 0, 1, 2...(n-1)$

$L = \sqrt{l(l+1)}\ \hbar$ (angular momentum magnitude)

magnetic quantum number $m_l = -l$ to $+l$

$L_z = m_l \hbar$ (z-component of $\vec{L}$)

spin quantum number $m_s = -\frac{1}{2},\ +\frac{1}{2}$

$S_z = m_s \hbar$ (z-comp., spin angular momentum)

shell ($2n^2$ states) = a value of (n) is given.

sub-shell [$2(2\ell + 1)$ states] = values of (n, l) are given.

orbital (2 states) = particular (n, l, m_l) are given.

state = particular (n, l, m_l, m_s) are given.

$l = 0, 1, 2, 3, 4, 5, 6...$ are indicated with respective letters: s, p, d, f, g, h,...

Pauli exclusion principle: *No two electrons in an atom can occupy the same quantum state.*

Subshells in order of increasing energy: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p

(They fill in order of increasing $n + l$, but higher n is higher energy if there is a tie.)

Periodic Table of the Elements§

Symbol — **Cl** 17 — Atomic Number
Atomic Mass§ — 35.4527
$3p^5$ — Electron Configuration (outer shells only)

Group I	Group II	Transition Elements										Group III	Group IV	Group V	Group VI	Group VII	Group VIII
H 1 1.00794 $1s^1$																	**He** 2 4.002602 $1s^2$
Li 3 6.941 $2s^1$	**Be** 4 9.012182 $2s^2$											**B** 5 10.811 $2p^1$	**C** 6 12.0107 $2p^2$	**N** 7 14.00674 $2p^3$	**O** 8 15.9994 $2p^4$	**F** 9 18.9984032 $2p^5$	**Ne** 10 20.1797 $2p^6$
Na 11 22.989770 $3s^1$	**Mg** 12 24.3050 $3s^2$											**Al** 13 26.981538 $3p^1$	**Si** 14 28.0855 $3p^2$	**P** 15 30.973761 $3p^3$	**S** 16 32.066 $3p^4$	**Cl** 17 35.4527 $3p^5$	**Ar** 18 39.948 $3p^6$
K 19 39.0983 $4s^1$	**Ca** 20 40.078 $4s^2$	**Sc** 21 44.955910 $3d^1 4s^2$	**Ti** 22 47.867 $3d^2 4s^2$	**V** 23 50.9415 $3d^3 4s^2$	**Cr** 24 51.9961 $3d^5 4s^1$	**Mn** 25 54.938049 $3d^5 4s^2$	**Fe** 26 55.845 $3d^6 4s^2$	**Co** 27 58.933200 $3d^7 4s^2$	**Ni** 28 58.6934 $3d^8 4s^2$	**Cu** 29 63.546 $3d^{10} 4s^1$	**Zn** 30 65.39 $3d^{10} 4s^2$	**Ga** 31 69.723 $4p^1$	**Ge** 32 72.61 $4p^2$	**As** 33 74.92160 $4p^3$	**Se** 34 78.96 $4p^4$	**Br** 35 79.904 $4p^5$	**Kr** 36 83.80 $4p^6$
Rb 37 85.4678 $5s^1$	**Sr** 38 87.62 $5s^2$	**Y** 39 88.90585 $4d^1 5s^2$	**Zr** 40 91.224 $4d^2 5s^2$	**Nb** 41 92.90638 $4d^4 5s^1$	**Mo** 42 95.94 $4d^5 5s^1$	**Tc** 43 (98) $4d^5 5s^2$	**Ru** 44 101.07 $4d^7 5s^1$	**Rh** 45 102.90550 $4d^8 5s^1$	**Pd** 46 106.42 $4d^{10} 5s^0$	**Ag** 47 107.8682 $4d^{10} 5s^1$	**Cd** 48 112.411 $4d^{10} 5s^2$	**In** 49 114.818 $5p^1$	**Sn** 50 118.710 $5p^2$	**Sb** 51 121.760 $5p^3$	**Te** 52 127.60 $5p^4$	**I** 53 126.90447 $5p^5$	**Xe** 54 131.29 $5p^6$
Cs 55 132.90545 $6s^1$	**Ba** 56 137.327 $6s^2$	57–71†	**Hf** 72 178.49 $5d^2 6s^2$	**Ta** 73 180.9479 $5d^3 6s^2$	**W** 74 183.84 $5d^4 6s^2$	**Re** 75 186.207 $5d^5 6s^2$	**Os** 76 190.23 $5d^6 6s^2$	**Ir** 77 192.217 $5d^7 6s^2$	**Pt** 78 195.078 $5d^9 6s^1$	**Au** 79 196.96655 $5d^{10} 6s^1$	**Hg** 80 200.59 $5d^{10} 6s^2$	**Tl** 81 204.3833 $6p^1$	**Pb** 82 207.2 $6p^2$	**Bi** 83 208.98038 $6p^3$	**Po** 84 (209) $6p^4$	**At** 85 (210) $6p^5$	**Rn** 86 (222) $6p^6$
Fr 87 (223) $7s^1$	**Ra** 88 (226) $7s^2$	89–103‡	**Rf** 104 (261) $6d^2 7s^2$	**Db** 105 (262) $6d^3 7s^2$	**Sg** 106 (266) $6d^4 7s^2$	**Bh** 107 (264) $6d^5 7s^2$	**Hs** 108 (269) $6d^6 7s^2$	**Mt** 109 (268) $6d^7 7s^2$	**Ds** 110 (271) $6d^9 7s^1$	111 (272) $6d^{10} 7s^1$	112 (277) $6d^{10} 7s^2$						

†Lanthanide Series

La 57 138.9055 $5d^1 6s^2$	**Ce** 58 140.115 $4f^1 5d^1 6s^2$	**Pr** 59 140.90765 $4f^3 5d^0 6s^2$	**Nd** 60 144.24 $4f^4 5d^0 6s^2$	**Pm** 61 (145) $4f^5 5d^0 6s^2$	**Sm** 62 150.36 $4f^6 5d^0 6s^2$	**Eu** 63 151.964 $4f^7 5d^0 6s^2$	**Gd** 64 157.25 $4f^7 5d^1 6s^2$	**Tb** 65 158.92534 $4f^9 5d^0 6s^2$	**Dy** 66 162.50 $4f^{10} 5d^0 6s^2$	**Ho** 67 164.93032 $4f^{11} 5d^0 6s^2$	**Er** 68 167.26 $4f^{12} 5d^0 6s^2$	**Tm** 69 168.93421 $4f^{13} 5d^0 6s^2$	**Yb** 70 173.04 $4f^{14} 5d^0 6s^2$	**Lu** 71 174.967 $4f^{14} 5d^1 6s^2$

‡Actinide Series

Ac 89 (227.02775) $6d^1 7s^2$	**Th** 90 232.0381 $6d^2 7s^2$	**Pa** 91 (231) $5f^2 6d^1 7s^2$	**U** 92 238.0289 $5f^3 6d^1 7s^2$	**Np** 93 (237) $5f^4 6d^1 7s^2$	**Pu** 94 (244) $5f^6 6d^0 7s^2$	**Am** 95 (243) $5f^7 6d^0 7s^2$	**Cm** 96 (247) $5f^7 6d^1 7s^2$	**Bk** 97 (247) $5f^9 6d^0 7s^2$	**Cf** 98 (251) $5f^{10} 6d^0 7s^2$	**Es** 99 (252) $5f^{11} 6d^0 7s^2$	**Fm** 100 (257) $5f^{12} 6d^0 7s^2$	**Md** 101 (258) $5f^{13} 6d^0 7s^2$	**No** 102 (259) $5f^{14} 6d^0 7s^2$	**Lr** 103 (262) $5f^{14} 6d^1 7s^2$

§ Atomic mass values averaged over isotopes in the percentages they occur on Earth's surface. For unstable elements, mass of the longest-lived known isotope is given in parentheses. 2003 revisions. (See also Appendix B.)