

Quantity	Symbol	Value	Units
Speed of light	c	$2.99792458 \times 10^8$	$\text{m s}^{-1}$
Elementary charge	e	$1.60217653 \times 10^{-19}$	C
Boltzmann constant	k	$1.3806505 \times 10^{-23}$	$\text{J K}^{-1}$
Gas Constant	R	8.314472	$\text{J K}^{-1} \text{mol}^{-1}$
Planck Constant	h	$6.6260693 \times 10^{-34}$	J s
$\hbar / 2\pi$	$\hbar$	$1.05457168 \times 10^{-34}$	J s
Avagadro's Number	NA	$6.0221415 \times 10^{23}$	$\text{mol}^{-1}$
Atomic mass constant (unit)	$m_u$	$1.66053886 \times 10^{-27}$	kg
mass of electron	$m_e$	$9.1093826 \times 10^{-31}$	kg
mass of proton	$m_p$	$1.67262171 \times 10^{-27}$	kg
mass of neutron	$m_n$	$1.67492728 \times 10^{-27}$	kg
Bohr radius	$a_0$	$5.291772108 \times 10^{-11}$	m
second radiation constant	$c_2$	$1.4387752 \times 10^{-2}$	m K
Stefan-Boltzmann constant	$\sigma$	$5.670400 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$
Standard acceleration of gravity	g	9.80665	$\text{m s}^{-2}$
Permittivity of free space	$\epsilon_0$	$8.85418782 \times 10^{-12}$	$\text{m}^{-3} \text{kg}^{-1} \text{s}^4 \text{A}^2$

$$1J = \frac{\text{kg m}^2}{\text{s}^2} \quad 1N = \frac{\text{kg m}}{\text{s}^2}$$

$$1eV = 1C * 1V = 1.6022 \times 10^{-19} J$$

$$1 \text{ hartree} = 1.436 \text{ E-18 J}$$

Some useful formulas and unit definitions

$$E = h\nu \quad c = \lambda\nu \quad \lambda = \frac{h}{p} \quad \hbar = \frac{h}{2\pi}$$

$$P^* = \frac{\text{Power}}{\text{Area}} = \epsilon\sigma T^4 \quad \lambda_{\text{max}} = \frac{C_2}{5T} \quad h\nu = \Phi + E_K$$

$$\hat{x} = x \quad \hat{p}_x = \frac{\hbar}{i} \frac{\partial}{\partial x} \quad \hat{I}_z = \frac{\hbar}{i} \frac{\partial}{\partial \phi} \quad \hat{\mu} = e r \quad \Delta x \Delta p \geq \frac{\hbar}{2}$$

$$\hat{H} = \hat{E}_x + \hat{V} \quad \hat{H}\psi = E\psi \quad \left[ -\frac{\hbar}{2m} \frac{\partial^2}{\partial x^2} + V(x) \right] \psi(x) = E\psi(x)$$

$$\left[ -\frac{\hbar}{2m} \nabla^2 + V(x, y, z) \right] \psi(x, y, z) = E\psi(x, y, z) \quad \left( \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) = \nabla^2 = \text{Laplacian}$$

$$\left[ -\frac{\hbar^2}{8\pi\mu} \nabla^2 - \frac{Ze^2}{4\pi\epsilon_0 r} \right] \psi(r, \theta, \phi) = E\psi(r, \theta, \phi) \quad \nabla^2 = \frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial}{\partial r} \right) + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left( \sin \theta \frac{\partial}{\partial \theta} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2}{\partial \phi^2}$$

$$\langle O \rangle = \int_{\text{all space}} \psi^* \hat{O} \psi d\tau \quad \text{for normalized wavefunctions} \quad d\tau = dx dy dz = r^2 \sin \theta dr d\theta d\phi$$

$$\text{Particle in 1D box} \quad \psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi}{L} x\right) \quad E_n = \frac{\hbar^2 \pi^2 n^2}{2m L^2}$$

$$\text{Particle in 2D box} \quad \psi_{n_x, n_y}(x, y) = \sqrt{\frac{2}{L_x}} \sqrt{\frac{2}{L_y}} \sin\left(\frac{n_x \pi}{L_x} x\right) \sin\left(\frac{n_y \pi}{L_y} y\right) \quad E_n = \frac{\hbar^2 \pi^2}{2m} \left( \frac{n_x^2}{L_x^2} + \frac{n_y^2}{L_y^2} \right)$$

$$\text{Harmonic oscillator} \quad V(x) = \frac{1}{2} kx^2 \quad \nu_{os} = \frac{1}{t} = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \quad E_n = \left( n + \frac{1}{2} \right) h\nu_{os}$$

$$\text{Particle on a ring} \quad \psi_n(\phi) = \sqrt{\frac{1}{\pi}} \sin(n\phi) \quad \psi_n(\phi) = \sqrt{\frac{1}{\pi}} \cos(n\phi) \quad E = \frac{n^2 \hbar^2}{2I}$$

$$\hat{L}_z Y_{l,m}(\theta, \phi) = m\hbar Y_{l,m}(\theta, \phi)$$

$$\hat{L}^2 Y_{l,m}(\theta, \phi) = l(l+1)\hbar^2 Y_{l,m}(\theta, \phi)$$

$$H_{average} = \int \phi^* \hat{H} \phi d\tau \geq E_0$$

$$E_{rot} = \frac{J(J+1)\hbar^2}{2I}$$

$$B = \frac{\hbar^2}{2I} = \frac{h^2}{8\pi^2 I}$$

$$\mu = \frac{m_1 m_2}{(m_1 + m_2)}$$

$$I = \frac{h^2}{8\pi^2 B} = \mu r^2$$

$$I = \sum_i m_i r_i^2$$

$$rate_{2 \leftarrow 1}(\text{stimulated}) = B_{21} N_1 \rho(\tilde{\nu})$$

$$rate_{2 \rightarrow 1}(\text{stimulated}) = B_{12} N_2 \rho(\tilde{\nu})$$

$$rate_{2 \rightarrow 1} = A_{12} N_2$$

$$A_{12} = 8\pi h c \tilde{\nu}_{21}^3 B_{12}$$

$$A_{12} = \frac{16\pi^3 \tilde{\nu}_{21}^3 |\mu_{21}|^2}{3h\epsilon_0 g_2}$$

$$B_{12} = \frac{2\pi^2 |\mu_{21}|^2}{3ch^2 \epsilon_0 g_2}$$

The Solutions to the Hydrogen atom (wavefunctions are in atomic units)

$$1s \quad \frac{1}{\sqrt{\pi}} Z^{\frac{3}{2}} e^{-Zr}$$

$$3s \quad \frac{1}{81\sqrt{3\pi}} Z^{\frac{3}{2}} (27 - 18Zr + 2Z^2 r^2) e^{-\frac{Zr}{3}}$$

$$2s \quad \frac{1}{4\sqrt{2\pi}} Z^{\frac{3}{2}} (2 - Zr) e^{-\frac{Zr}{2}}$$

$$3p_x \quad \frac{\sqrt{2}}{81\sqrt{\pi}} Z^{\frac{3}{2}} r (6 - Zr) e^{-\frac{Zr}{3}} \sin\theta \cos\phi$$

$$2p_x \quad \frac{1}{4\sqrt{2\pi}} Z^{\frac{3}{2}} r e^{-\frac{Zr}{2}} \sin\theta \cos\phi$$

$$3p_y \quad \frac{\sqrt{2}}{81\sqrt{\pi}} Z^{\frac{3}{2}} r (6 - Zr) e^{-\frac{Zr}{3}} \sin\theta \sin\phi$$

$$2p_y \quad \frac{1}{4\sqrt{2\pi}} Z^{\frac{3}{2}} r e^{-\frac{Zr}{2}} \sin\theta \sin\phi$$

$$3p_z \quad \frac{\sqrt{2}}{81\sqrt{\pi}} Z^{\frac{3}{2}} r (6 - Zr) e^{-\frac{Zr}{3}} \cos\theta$$

$$2p_z \quad \frac{1}{4\sqrt{2\pi}} Z^{\frac{3}{2}} r e^{-\frac{Zr}{2}} \cos\theta$$

$$E_n = \left( -\frac{\mu_e e^4}{8\epsilon_0^2 h^2} \frac{Z^2}{n^2} \right)_{\text{SI units}} = \left( -\frac{Z^2}{n^2} \right)_{\text{atomic units}}$$

### The Periodic Table of the Elements

1 <b>H</b> Hydrogen 1.00794																	2 <b>He</b> Helium 4.003																		
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.012182											5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.0107	7 <b>N</b> Nitrogen 14.00674	8 <b>O</b> Oxygen 15.9994	9 <b>F</b> Fluorine 18.9984032	10 <b>Ne</b> Neon 20.1797																		
11 <b>Na</b> Sodium 22.989769	12 <b>Mg</b> Magnesium 24.3050											13 <b>Al</b> Aluminum 26.981538	14 <b>Si</b> Silicon 28.0855	15 <b>P</b> Phosphorus 30.973761	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.4527	18 <b>Ar</b> Argon 39.948																		
19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.955910	22 <b>Ti</b> Titanium 47.887	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.938049	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933200	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.39	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.61	33 <b>As</b> Arsenic 74.92160	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.80																		
37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90585	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.90550	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.757	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.29																		
55 <b>Cs</b> Cesium 132.90545	56 <b>Ba</b> Barium 137.327	57 <b>La</b> Lanthanum 138.9055	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.9479	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.227	78 <b>Pt</b> Platinum 195.078	79 <b>Au</b> Gold 196.96655	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98038	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)																		
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89 <b>Ac</b> Actinium (227)	104 <b>Rf</b> Rutherfordium (261)	105 <b>Db</b> Dubnium (262)	106 <b>Sg</b> Seaborgium (263)	107 <b>Bh</b> Bohrium (262)	108 <b>Hs</b> Hassium (265)	109 <b>Mt</b> Meitnerium (269)	110	111 (271)	112 (277)	113	114																						
																		58 <b>Ce</b> Cerium 140.116	59 <b>Pr</b> Praseodymium 140.90765	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium (145)	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.964	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.92534	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93032	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93421	70 <b>Yb</b> Ytterbium 173.04	71 <b>Lu</b> Lutetium 174.967				
																		90 <b>Th</b> Thorium 232.0381	91 <b>Pa</b> Protactinium 231.03588	92 <b>U</b> Uranium 238.0289	93 <b>Np</b> Neptunium (237)	94 <b>Pu</b> Plutonium (244)	95 <b>Am</b> Americium (243)	96 <b>Cm</b> Curium (247)	97 <b>Bk</b> Berkelium (247)	98 <b>Cf</b> Californium (251)	99 <b>Es</b> Einsteinium (252)	100 <b>Fm</b> Fermium (257)	101 <b>Md</b> Mendelevium (258)	102 <b>No</b> Nobelium (259)	103 <b>Lr</b> Lawrencium (260)				