

Physics Formula Sheet

402-0023-01L Physics

2023/ 2024

Constants

Constant	Symbol	Value
Speed of light	c	3.00×10^8 m/s
Gravitational constant	G	6.674×10^{-11} N(m/kg) ²
Planck's constant	h	6.626×10^{-34} J.s
Mass of the electron	m_e	9.10939×10^{-31} kg
Mass of the proton	m_p	1.67262×10^{-27} kg
Charge of the electron	$-e$	-1.60218×10^{-19} C
Permittivity of free space	ϵ_0	8.85419×10^{-12} C ² /J m
Boltzmann constant	k_B	1.38066×10^{-23} J/ K
Avogadro's constant	N_A	6.022×10^{23} 1/mol

Classical Physics

Title	Equation
Bragg's Reflection	$n\lambda = 2d \sin(\theta)$
Diffraction (Single Slit)	$\lambda = d \sin(\theta)$
Young's Double Slit	$\frac{\Delta x}{L} = \frac{\lambda}{d} \approx \sin \theta$
Heat Transfer (Fourier's Law)	$\dot{Q} = mC_v \Delta T$
Continuity Equation	$\nabla \cdot \mathbf{J} = -\frac{dq}{dt}$
Force of Gravity	$F = G \frac{m_1 m_2}{r^2}$
Coulomb Force	$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$
Special Relativity (Time Dilation)	$E^2 = (pc)^2 + (m_0 c^2)^2$

Nuclear and magnetic physics

Magnetic Field	$E_B = -\mu B,$ $\mu = \frac{e}{2m} \hbar$ $F_z = -\frac{\partial E}{\partial F_z} = \mu \frac{\partial B}{\partial z}$
Rigid rotator	$E_{rot} = \frac{L^2}{2I}$ $I = \frac{m_1 r_1^2 + m_2 r_2^2}{2}$
Radioactive decay	$N(t) = N(0) \exp^{-\lambda t} = N(0) (\frac{1}{2})^{t/\tau_{1/2}}$ $\tau_{1/2} = \ln(2)/\lambda$

Thermodynamics

0th law: If two objects are in thermal equilibrium with a third object, then all three objects are in thermal equilibrium with each other.

1st law: For any process concerning a given system, the change in internal energy ΔU of that system is equal to the sum of the heat Q transferred to that system and the work W performed on that system, or:

2nd law: Carnot: Wherever there exists a difference in temperature, motive power can be produced.

Kelvin: It is impossible for a self acting machine to convey heat from a colder body to a hotter.
Clausius: Heat cannot flow from a colder to hotter body without another process occurring, connected therewith, simultaneously.

$$T = (\frac{dU}{dS})_{V, N}$$

$$\text{Energy per mode: } < E_{\text{mode}} > = \frac{3}{2} k_B T$$

$$Q = C \Delta T \quad Q = \int_{T_1}^{T_2} C(T) dT$$

$$L = \frac{Q_{\text{latent}}}{m}$$

$$\gamma = \frac{C_p}{C_v} \quad dS = \frac{\delta Q_{\text{rev}}}{T}$$

Electrostatics and dynamics

$$\vec{F} = \sum_{i=1}^N \frac{q_i q_j (\vec{r} - \vec{r}_j)}{4\pi\epsilon_0 |\vec{r} - \vec{r}_j|^3} \quad \text{Torque: } \vec{\tau} = \vec{p} \times \vec{E}$$

$$\text{Energy of a dipole: } U(\theta) = -\vec{p} \cdot \vec{E}$$

$$\text{Gauss' law: } \phi = \oint_{\vec{S}} \mathbf{E} \cdot d\mathbf{A}$$

$$\text{Potential: } \Delta V \equiv \frac{\Delta U}{q} = - \int_C \vec{E} \cdot d\vec{l} \quad \text{Energy of a capacitor: } U = \frac{Q^2}{2C}$$

$$\text{Current: } I = \dot{Q}$$

$$\text{Potential: } V_b - V_a = - \int_a^b \vec{E} \cdot d\vec{l}$$

$$\text{Kirchhoff's rules: 1: } \sum_{j, \text{loop}} \Delta V_j$$

$$2: \sum_j I_{j, \text{into node}} = 0$$

$$\text{Magnetic force: } \vec{F} = q\vec{v} \times \vec{B}$$

Black body:

$$D(k)dk = \frac{\partial N(k)}{\partial k} \frac{dk}{V} = \frac{k^2}{\pi^2} dk$$

$$D(\omega)d\omega = \frac{\omega^2}{\pi^2 c^3} d\omega$$

$$u(\omega)d\omega = \frac{\omega^2}{\pi^2 c^3} k_B T d\omega \quad \text{classical limit}$$

$$u(\omega)d\omega = \frac{h\omega^3}{\pi^2 c^3} \frac{1}{\exp(\frac{h\omega}{k_B T}) - 1} d\omega$$

$$I(\omega) = cu(\omega)d\omega$$

Quantum Mechanics

$$\text{Time-dependent Schrodinger's Equation: } i\hbar \frac{\partial}{\partial t} \Psi(\vec{r}, t) = \left[-\frac{\hbar^2}{2m} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) + V(x) \right] \Psi$$

$$\text{Energy of a photon: } E = hf$$

$$\text{Time-independent Schrodinger's Equation: } E\phi = \hat{H}\phi = \left(-\frac{\hbar^2}{2m} \nabla^2 + V(x) \right) \cdot \phi$$

$$\text{Energy of a photon: } E = hf$$

$$\text{Infinite potential well: } E_n = \frac{\hbar^2}{2m} k_n^2 = \frac{\hbar^2 \pi^2 n^2}{2mL^2} = n^2 E_0, \quad \psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right), \quad E_0 = \frac{\hbar^2 \pi^2}{2mL^2}$$

$$\text{Transmission through a barrier: } T = \frac{4E(V_0 - E)}{4E(V_0 - E) + V_0^2 \sinh^2[\sqrt{2m(V_0 - E)} \frac{l}{\hbar}]}$$

$$T \approx \frac{16E(V_0 - E)}{V_0^4} e^{-2\rho_2 l}, \quad \text{with } \rho_2 = \sqrt{\frac{2m(V_0 - E)}{\hbar^2}}, \quad \rho_2 \cdot l \gg 1$$

$$\text{De Broglie wavelength: } \lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$$

$$\text{Photoelectric effect: } h\nu - \phi_0 = \frac{1}{2}mv^2 = eV$$

$$\text{Bohr-Sommerfeldt condition: } \oint_C \mathbf{p} \cdot d\mathbf{s} = nh, \quad 2\pi r = nh(\text{circular orbit})$$

$$\text{Probability current: } j = \frac{\hbar}{2mi} (\psi^* \frac{\partial \Psi}{\partial x} - \Psi \frac{\partial \Psi^*}{\partial x})$$

$$\text{Compton scattering: } \lambda_2 - \lambda_1 = \frac{h}{m_0 c} (1 - \cos \theta)$$

$$h\nu_1 + m_0 c^2 = h\nu_2 + \sqrt{m_0^2 c^4 + p_e^2 c^2}$$

Mathematical equations

Trigonometric functions:

$$\int \sin^n ax dx = -\frac{1}{a} \cos ax {}_2F_1 \left[\frac{1}{2}, \frac{1-n}{2}, \frac{3}{2}, \cos^2 ax \right]$$

$$\int \sin^2 ax dx = \frac{x}{2} - \frac{1}{4a} \sin 2ax + C \quad (1)$$

$$\int x \sin^2 ax dx = \frac{x^2}{4} - \frac{x}{4a} \sin 2ax - \frac{1}{8a^2} \cos 2ax + C \quad (2)$$

$$\int x^2 \sin^2 ax dx = \frac{x^3}{6} - \left(\frac{x^2}{4a} - \frac{1}{8a^3} \right) \sin 2ax - \frac{x}{4a^2} \cos 2ax + C \quad (3)$$

$$\int \tan ax dx = -\frac{1}{a} \ln |\cos ax| + C = \frac{1}{a} \ln |\sec ax| + C \quad (4)$$

$$\int \frac{\cos ax}{x} dx = \ln |ax| + \sum_{k=1}^{\infty} (-)^k \frac{(ax)^{2k}}{2k(2k)!} + C \quad (5)$$

$$\int \cos^2 ax dx = \frac{x}{2} + \frac{1}{4a} \sin 2ax + C \quad (6)$$

$$\int \sin^3 ax dx = \frac{\cos 3ax}{12a} - \frac{3 \cos ax}{4a} + C \quad (7)$$

$$\int \tan^2 x dx = \tan x - x + C \quad (8)$$

$$\int \sin ax \cos ax dx = -\frac{\cos^2 ax}{2a} + C \quad (9)$$

$$\int x \cos ax dx = \frac{\cos ax}{a^2} + \frac{x \sin ax}{a} + C \quad (10)$$

$$\int \cos ax dx = \frac{1}{a} \sin ax + C \quad (11)$$

$$\int x \sin ax dx = \frac{\sin ax}{a^2} - \frac{x \cos ax}{a} + C \quad (12)$$

$$\int (\sin ax)(\cos^n ax) dx = -\frac{1}{a(n+1)} \cos^{n+1} ax + C \quad (13)$$

Exponential functions:

$$\int_{-\infty}^{\infty} e^{-ax^2} dx = \sqrt{\frac{\pi}{a}} \quad (a > 0) \quad (14)$$

$$\int_{-\infty}^{\infty} x e^{-ax^2 + bx} dx = \frac{\sqrt{\pi b}}{2a^{3/2}} e^{\frac{b^2}{4a}} \quad (\Re(a) > 0) \quad (15)$$

$$\int_{-\infty}^{\infty} x^n e^{-ax} dx = \begin{cases} \frac{\Gamma(n+1)}{a^{n+1}} & (n > -1, a > 0) \\ \frac{n!}{a^{n+1}} & (n = 0, 1, 2, \dots, a > 0) \end{cases} \quad (16)$$

$$\int_{-\infty}^{\infty} x^2 e^{-ax^2} dx = \frac{1}{2} \sqrt{\frac{\pi}{a^3}} \quad (a > 0) \quad (17)$$

$$\int x e^{cx} dx = \left(\frac{x}{c} - \frac{1}{c^2} \right) e^{cx} \quad (18)$$

$$\int x^2 e^{cx} dx = \left(\frac{x^2}{c} - \frac{2x}{c^2} + \frac{2}{c^3} \right) e^{cx} \quad (19)$$

$$\int x^4 e^{-ax^2} dx = \sqrt{\frac{\pi}{a}} \frac{3}{4a^2} \quad (20)$$

Spherical coordinates

$$x = r \sin \theta \cos \phi$$

$$y = r \sin \theta \sin \phi$$

$$z = r \cos \theta$$

Volume fraction:

$$dV = r^2 \sin \theta dr d\theta d\phi$$

Solid angle:

$$d\Omega = \frac{dS_r}{r^2} = \sin \theta d\theta d\phi$$

Surface element:

$$dS_r = r^2 \sin \theta d\theta d\phi$$

$$\nabla f = \frac{\partial f}{\partial r} \hat{r} + \frac{1}{r} \frac{\partial f}{\partial \theta} \hat{\theta} + \frac{1}{r \sin \theta} \frac{\partial f}{\partial \phi} \hat{\phi} \quad (21)$$

$$\text{div } \mathbf{F} = \nabla \cdot \mathbf{F} = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 F_r) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \theta} (\sin \theta F_\theta) + \frac{1}{r \sin \theta} \frac{\partial F_\phi}{\partial \phi} \quad (22)$$

$$\begin{aligned}\nabla \times \mathbf{F} &= \frac{1}{r \sin \theta} \left(\frac{\partial}{\partial \theta} (A_\phi \sin \theta) - \frac{\partial A_\theta}{\partial \phi} \right) \vec{r} \\ &\quad + \frac{1}{r} \left(\frac{\partial A_r}{\sin \theta} \frac{\partial}{\partial \phi} - \frac{\partial}{\partial r} (r A_\phi) \right) \vec{\theta} \\ &\quad + \frac{1}{r} \left(\frac{\partial}{\partial r} (r A_\theta) - \frac{\partial A_r}{\partial \phi} \right) \vec{\phi}\end{aligned}\quad (23)$$

$$\begin{aligned}\nabla^2 f &= \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial f}{\partial r} \right) + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial f}{\partial \theta} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 f}{\partial \phi^2} = \\ &\quad \left(\frac{\partial^2}{\partial r^2} + \frac{2}{r} \frac{\partial}{\partial r} \right) f + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial f}{\partial \theta} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 f}{\partial \phi^2}\end{aligned}\quad (24)$$

Harmonic oscillator:

First four harmonic oscillator wavefunction	Hermite polynomials	E _n
$\psi_0(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} e^{-\frac{1}{2}\xi^2}$	1	$\frac{1}{2}\hbar\omega$
$\psi_1(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} \sqrt{2}\xi e^{-\frac{1}{2}\xi^2}$	2y	$\frac{3}{2}\hbar\omega$
$\psi_2(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} \frac{1}{\sqrt{2}} (2\xi^2 - 1) e^{-\frac{1}{2}\xi^2}$	4y ² - 2	$\frac{5}{2}\hbar\omega$
$\psi_3(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} \frac{1}{\sqrt{3}} (2\xi^3 - 3\xi) e^{-\frac{1}{2}\xi^2}$	8y ³ - 12y	$\frac{7}{2}\hbar\omega$
Harmonic oscillator	$\psi_n(x) = \frac{1}{\sqrt{2^n n!}} \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} (a^\dagger)^n e^{-\frac{1}{2}\frac{m\omega}{\hbar}x^2} \psi_0(x)$	
Raising operator	$a^\dagger = \frac{1}{\sqrt{2\hbar m\omega}} (m\omega x - ip)$	
Lowering operator	$a = \frac{1}{\sqrt{2\hbar m\omega}} (m\omega x + ip)$	
$a^\dagger n\rangle = \sqrt{n+1} n+1\rangle$	$a n\rangle = \sqrt{n} n-1\rangle$	
Number operator	$\hat{N} = a^\dagger a, \hat{N} n\rangle = n n\rangle$	
Commutation relation	$[a, a^\dagger] = aa^\dagger - a^\dagger a = 1$	
Hamiltonian	$\hat{H} = \hbar\omega \left(\hat{N} + \frac{1}{2} \right)$	

Inner product and expectation

Expectation value (discrete)

$$\langle f_i \rangle = \sum_i P_i f_i$$

Expectation value (continuous)

$$\langle f(x) \rangle = \int_{-\infty}^{\infty} f(x) P(x) dx$$

$$\langle \hat{O} \rangle = \int \psi^*(\mathbf{r}) \hat{O} \psi(\mathbf{r}) d^3r$$

Inner product

$$\langle \psi | \phi \rangle = \int \psi^*(x) \phi(x) dx$$

Variance

$$\sigma_f^2 = \langle f^2 \rangle - \langle f \rangle^2$$

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$$L^2 = -\hbar^2 \left(\frac{1}{\sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial}{\partial \theta} \right) + \frac{1}{\sin^2 \theta} \frac{\partial^2}{\partial \phi^2} \right)$$

Hund’s rule

- 1: All other thing being equal, the state with the highest total spin (S), will have the lowest.
- 2: For a given spin, the state the highest total orbital angular momentum (L), consistent with overall anti-symmetrization, will have the lowest energy.
- 3: If a subshell (n, l) is no more than half filled, then the lowest energy level has $J = |L - S|$: if it is more than half filled, then $J = L + S$ has the lowest energy.

Spin

Two particle spin states

$$\begin{aligned}|0, 0\rangle &= \frac{1}{\sqrt{2}} (|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle) \quad s = 0 \text{ singlet} \\ |1, 0\rangle &= \frac{1}{\sqrt{2}} (|\uparrow\downarrow\rangle + |\downarrow\uparrow\rangle), \quad s = 1 \text{ triplet} \\ |1, -1\rangle &= |\downarrow\downarrow\rangle\end{aligned}$$

$$S_x = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad S_y = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad S_z = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad S^2 = \frac{3}{4}\hbar^2 \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad S_+ = \hbar \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \quad S_- = \hbar \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix}$$

Two particle Hamiltonian:

$$\hat{H} = -\frac{\hbar^2}{2m_1} \nabla_1^2 - \frac{\hbar^2}{2m_2} \nabla_2^2 + V(\mathbf{r}_1, \mathbf{r}_2)$$

Hamiltonian with an atom with atomic number Z:

$$\hat{H} = -\frac{\hbar^2}{2m_e} \nabla^2 - \frac{Ze^2}{4\pi\epsilon_0 r}$$

Commutation relations

$$\begin{aligned}[A, B] &= AB - BA \\ [AB, C] &= A[B, C] - [A, C]B \\ [x, p_x] &= i\hbar \\ [y, p_y] &= i\hbar \\ [x, y] &= [x, p_y] = [y, p_x] = 0\end{aligned}$$

Hydrogen atom

Fine structure constant:

$$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} \approx \frac{1}{137}$$

Bohr radius:

$$a_0 = \frac{\hbar}{m_e c \alpha} \approx 0.529 \times 10^{-10} \text{m}$$

Bohr energy:

$$E_n = -\frac{2\pi^2 k^2 e^4 m_e}{\hbar^2 n^2}$$

Ground state energy:

$$E_1 = -13.6 \text{eV}$$

Wave function:

$$\psi_{nlm}(r, \theta, \phi) = R_{nl}(r) Y_{lm}(\theta, \phi)$$

Rydberg formula:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Rydberg constant:

$$R_H \approx 1.097 \times 10^7 \text{m}^{-1}$$

Radial wavefunctions:

$$R_{nl}(r) = N_{nl} r^l e^{-r/a_0} L_{n-l-1}^{2l+1}(\rho)$$

Legendre polynomials

Angular momentum

$$L_+ = L_x + iL_y$$

$$L_- = L_x - iL_y$$

$$L^2 = L_x^2 + \frac{1}{2}(L_+ L_- + L_- L_+)$$

$$[L_x, L_y] = i\hbar L_z$$

$$[L^2, L_i] = 0 \quad \text{where } i = x, y, \text{ or } z$$

$$L_x = -i\hbar \left(\sin \phi \frac{\partial}{\partial \theta} + \cot \theta \cos \phi \frac{\partial}{\partial \phi} \right), \quad L_y = i\hbar \left(\cos \phi \frac{\partial}{\partial \theta} - \cot \theta \sin \phi \frac{\partial}{\partial \phi} \right), \quad L_z = -i\hbar \frac{\partial}{\partial \phi}$$

$$L_+ = \hbar e^{i\phi} \left(\frac{\partial}{\partial \theta} + i \cot \theta \frac{\partial}{\partial \phi} \right), \quad L_- = \hbar e^{-i\phi} \left(-\frac{\partial}{\partial \theta} + i \cot \theta \frac{\partial}{\partial \phi} \right)$$

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Clebsch-Gordan coefficients

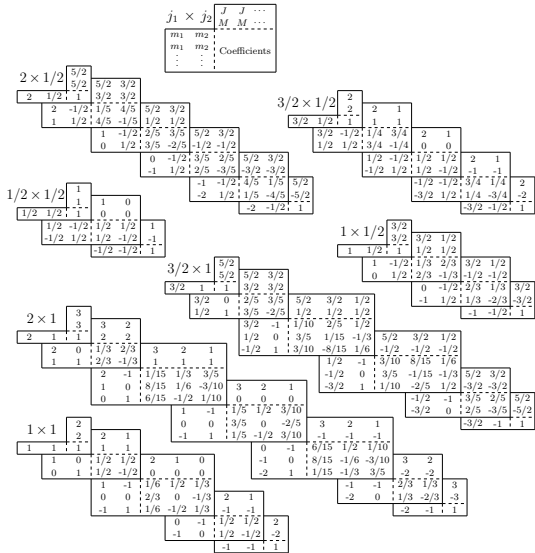


Figure 1: Clebsch-Gordan coefficients. A square root is understood on each coefficient, that is, $-1/3$ means $-\sqrt{1/3}$.

Condensed Matter

Free electron gas:

$$\psi_{n_x, n_y, n_z}(\mathbf{r}) = \sqrt{\frac{8}{V}} \sin\left(\frac{n_x \pi x}{L_x}\right) \sin\left(\frac{n_y \pi y}{L_y}\right) \sin\left(\frac{n_z \pi z}{L_z}\right), \quad E(\mathbf{k}) = \frac{\hbar^2 k^2}{2m}$$

Fermi energy of a metal:

$$E_F = \frac{\hbar^2 k_F^2}{2m}, \quad \rho \equiv \frac{N_q}{V}, \quad N_q = \text{number of electrons in volume } V, \quad n_e = n_i \exp\left(\frac{E_F - E_i}{k_B T}\right)$$

Density of states:

$$3D: g(E) = \frac{V m}{2\pi^2 \hbar^3} \sqrt{2mE}, \quad 2D: g(E) = \frac{m}{\pi \hbar^2}$$

Distribution functions:

$$\begin{array}{ccc} \text{Maxwell-Boltzmann} & \text{Fermi-Dirac} & \text{Bose-Einstein} \\ f(E) = e^{-\frac{E}{k_B T}} & f(E) = \frac{1}{e^{\frac{E}{k_B T}} + 1} & f(E) = \frac{1}{e^{\frac{E}{k_B T}} - 1} \end{array}$$

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First order perturbation theory:

$$\Delta E_n^{(1)} = \langle \psi_n^0 | \hat{H}' | \psi_n^0 \rangle, \psi_n^{(1)} = \sum_{m \neq n} \frac{\langle \psi_m^0 | \hat{H}' | \psi_n^0 \rangle}{E_n^{(0)} - E_m^{(0)}} \psi_m^{(0)}$$

1 IA																18 VIIIA						
1	H Hydrogen																2 He Helium					
2	Li Lithium		Be Beryllium												3 B Boron	4 C Carbon	5 N Nitrogen	6 O Oxygen	7 F Fluorine	8 Ne Neon		
3	Na Sodium		Mg Magnesium		3 IIIA	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA Al Aluminum	14 IVA Si Silicon	15 VA P Phosphorus	16 VIA S Sulfur	17 VIIA Cl Chlorine	18 VIIIA Ar Argon		
4	K Potassium		Ca Calcium		3 Sc Scandium	4 Ti Titanium	5 V Vanadium	6 Cr Chromium	7 Mn Manganese	8 Fe Iron	9 Co Cobalt	10 Ni Nickel	11 Cu Copper	12 Zn Zinc	13 Ga Gallium	14 Ge Germanium	15 As Arsenic	16 Se Selenium	17 Br Bromine	18 Kr Krypton		
5	Rb Rubidium		Sr Strontium		3 Y Yttrium	4 Zr Zirconium	5 Nb Niobium	6 Mo Molybdenum	7 Tc Technetium	8 Ru Ruthenium	9 Rh Rhodium	10 Pd Palladium	11 Ag Silver	12 Cd Cadmium	13 In Indium	14 Sn Tin	15 Sb Antimony	16 Te Tellurium	17 I Iodine	18 Xe Xenon		
6	Cs Cesium		Ba Barium		3 La-Lu Lanthanum-Lutetium	4 Hf Hafnium	5 Ta Tantalum	6 W Tungsten	7 Re Rhenium	8 Os Osmium	9 Ir Iridium	10 Pt Platinum	11 Au Gold	12 Hg Mercury	13 Tl Thallium	14 Pb Lead	15 Bi Bismuth	16 Po Polonium	17 At Astatine	18 Rn Radon		
7	Fr Francium		Ra Radium		3 Ac-Lr Actinium-Lutetium	4 Rf Rutherfordium	5 Db Dubnium	6 Sg Seaborgium	7 Bh Bohrium	8 Hs Hassium	9 Mt Meitnerium	10 Ds Darmstadtium	11 Rg Roentgenium	12 Uub Ununbium	13 Uut Ununtrium	14 Uuq Ununquadium	15 Uup Ununpentium	16 Uuh Ununhexium	17 Uus Ununseptium	18 Uuo Ununoctium		
<div><div>Alkali Metals</div><div>Alkaline Earth Metals</div><div>Transition Metals</div><div>Inner Transition Metals</div><div>Lanthanides</div><div>Actinides</div><div>Hydrogen</div><div>Carbon Group</div><div>Chalcogens</div><div>Halogens</div><div>Noble Gases</div><div>Metals</div><div>Nonmetals</div><div>Metalloids</div><div>Unlabeled</div></div>																					87-118	
<div><div>Symbol</div><div>Atomic Number</div><div>Atomic Weight</div><div>Element Name</div><div>Element Category</div></div>																					89-104	
<div><div>Ac</div><div>Th</div><div>Pa</div><div>U</div><div>Np</div><div>Pu</div><div>Am</div><div>Cm</div><div>Bk</div><div>Cf</div><div>Es</div><div>Fm</div><div>Md</div><div>No</div><div>Lr</div></div>																					105-118	
<div><div>La</div><div>Ce</div><div>Pr</div><div>Nd</div><div>Pm</div><div>Sm</div><div>Eu</div><div>Gd</div><div>Tb</div><div>Dy</div><div>Ho</div><div>Er</div><div>Tm</div><div>Yb</div><div>Lu</div></div>																					119-118	