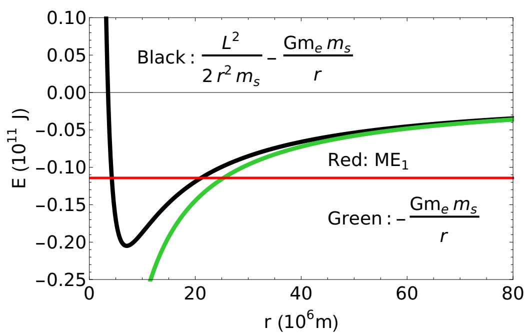
Physics 132-1 Final Exam

I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

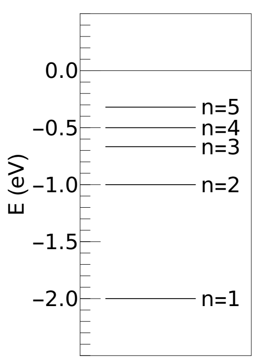
Signature ______________________________

Questions (10 for 4 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. Consider the figure which shows several curves related to the energy of the particle. What restrictions are there on the energy E of a classical particle based on the figure? Explain.



2. The figure shows the complete level diagram for some atom. What are the chances of this atom emitting a photon of energy $E_1 = 0.5\ eV$ versus a photon of energy $E_2 = 0.9\ eV$? Explain.



3. When we measured the latent heat of vaporization of liquid nitrogen we used a resistor immersed in the liquid as the heat source. We took some data with the current in the resistor turned off. Why?

4. In our study of the kinetic theory of ideal gases we found that

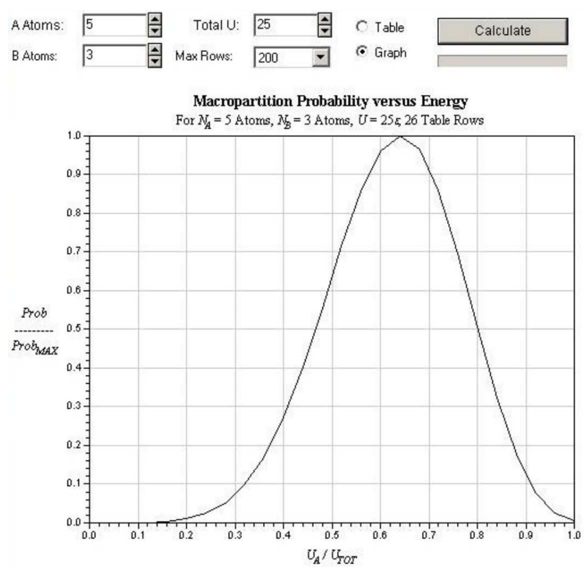
$$F_x = \frac{mv_x^2}{l}$$

where m is the mass and v_x is the horizontal component of the velocity of a gas particle. We have assumed from the beginning that we have a cubical box of edge length l. Show that the pressure on the wall perpendicular to the x axis caused by the force F_x due to *one* molecule is described by the following expression.

$$P = \frac{mv_x^2}{l^3}.$$

Clearly show all steps for full credit.

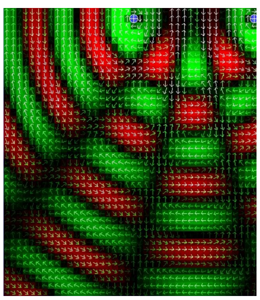
5. The figure shows the output of the `StatMech` program consisting of a window showing the graph of probabilities relative to the most probable state for each microstate for two solids A and B in contact. The horizontal axis is the fraction of the energy in solid A divided by the total energy. How wide is the distribution of microstates? How would you expect this width to change as the number of particles increased? Explain your reasoning.



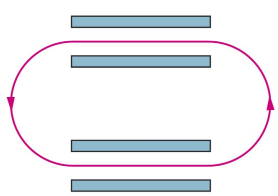
6. Recall the electroscope. How did you charge the electroscope by induction?

7. Recall our study of the electric potential of a point charge and an electric dipole. Both produced potentials that decreased with increasing r the distance from the charges. Which one decreased more quickly with r when you were far from the charges? Explain your result.

8. Consider the simulation below of electromagnetic waves from two point sources. Label areas on the figure where waves from the two sources combine to cancel each other out (destructive interference) and areas where their amplitudes add (constructive interference). If these were visible light waves, where would you see bright light? Explain. In what direction does the Poynting vector point?



9. The figure shows the path of an electron in a region of uniform magnetic field. The path consists of two straight sections, each between a pair of uniformly charged plates, and two half-circles. Which plate is at the higher electric potential in (a) the top pair of plates and (b) the bottom pair? (c) What is the direction of the magnetic field? Explain your reasoning.



10. The radioactive nucleus $^{226}_{88}$Ra has a half-life of about $1.6 \times 10^3\ yr$. If the Solar System is about 5 billion (10^9) years old, how can there be any of these nuclei left?

Problems (6). Clearly show all reasoning for full credit. Use a separate sheet to show your work.

1. 10 pts. What are the energy and wavelength of a photon emitted when a hydrogen atom undergoes a transition from the $n = 4$ state to the $n = 3$ state?

2. 10 pts. A Russian Arktica satellite that monitors polar weather follows an elliptical orbit around the Earth at an altitude of $h = 300\ km$ above the surface of the Earth (radius $r_E = 6.67 \times 10^6\ m$) at a velocity

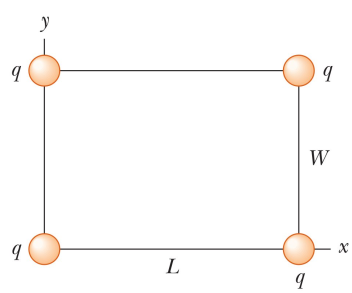
$$\vec{v} = 4.1 \times 10^3\ m/s\ \hat{r} + 7.5 \times 10^3\ m/s\ \hat{\theta} \qquad .$$

What is the angular momentum? What is the total energy? The satellite mass is $m_s = 600\ kg$.

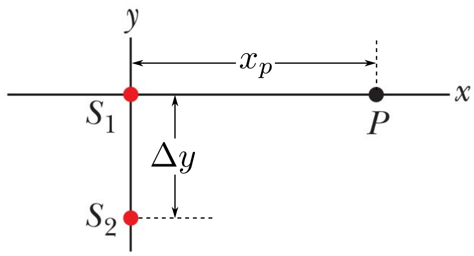
3. 10 pts. A room of volume V_0 contains air having equivalent molar mass M (in g/mol). If the temperature of the room is raised from T_1 to T_2, what mass of air will leave the room? Assume that the air pressure in the room is maintained at P_0 and get your answer in terms of P_0, V_0, the temperatures, and any other necessary constants.

4. 10 pts. Imagine that the entropy of a certain substance as a function of N and E is given by the formula $S = Nk_b \ln E$. How is the thermal energy of this substance is related to its temperature?

5. 10 pts. Four identical point charges ($q = 10.0\ \mu C$) are located on the corners of a rectangle as shown in the figure. The dimensions of the rectangle are $L = 60.0\ cm$ and $W = 15.0\ cm$. Calculate the magnitude and direction of the resultant electric force exerted on the charge at the lower left corner by the other three charges.



6. 10 pts. In the figure two isotropic point sources of light (S_1 and S_2) are separated by distance $\Delta y = 2.70\ \mu m$ along the y axis and emit light in phase at wavelength $\lambda = 900\ nm$ and with the same amplitude. A light sensor is located at point P at x_P on the x axis. The distance x_p is not necessarily much larger than the separation Δy of the sources. What is the greatest value of x_P at which the detected light is a minimum due to destructive interference?



Physics 132-1 Constants

Avogadro's number (N_A)	6.022×10^{23}	Speed of light (c)	$3 \times 10^8\ m/s$
Boltzmann constant (k_B)	$1.38 \times 10^{-23}\ J/K$	proton/neutron mass	$1.67 \times 10^{-27}\ kg$
atomic mass unit (u)	$1.66 \times 10^{-27}\ kg$	g	$9.8\ m/s^2$
Gravitation constant (G)	$6.67 \times 10^{-11}\ N-m^2/kg^2$	Earth's radius	$6.37 \times 10^6\ m$
Coulomb constant (k_e)	$8.99 \times 10^9 \frac{N-m^2}{C^2}$	Earth's mass	$5.98 \times 10^{24}\ kg$
Electron mass	$9.11 \times 10^{-31}\ kg$	Earth-Sun distance	$1.5 \times 10^{11}\ m$
Elementary charge (e)	$1.60 \times 10^{-19}\ C$	Proton/Neutron mass	$1.67 \times 10^{-27}\ kg$
Permittivity constant (ϵ_0)	$8.85 \times 10^{-12} \frac{kg^2}{N-m^2}$	1.0 eV	$1.6 \times 10^{-19}\ J$
1 MeV	$10^6\ eV$	atomic mass unit (u)	$1.66 \times 10^{-27}\ kg$
Planck's constant (h)	$6.626 \times 10^{-34}\ J-s$	Planck's constant (h)	$4.14 \times 10^{-15}\ eV-s$
Planck's constant 2 ($\hbar = h/2\pi$)	$1.0546 \times 10^{-34}\ J-s$	Gas constant R	$8.315\ J/K-mol$
Planck's constant 2 ($\hbar = h/2\pi$)	$6.58 \times 10^{-16} J/K-mole$	Permittivity constant (ϵ_0)	$8.85 \times 10^{-12} \frac{kg^2}{N-m^2}$

Physics 132-1 Equation Sheet, Final

$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt} \quad a_c = \frac{v^2}{r} \quad \vec{F}_c = -m\frac{v^2}{r}\hat{r} \qquad KE = \frac{1}{2}mv^2 \quad ME_0 = ME_1 = KE_1 + PE_1 \quad \vec{p} = m\vec{v} \quad \vec{p}_0 = \vec{p}_1$$

$$x = \frac{a}{2}t^2 + v_0 t + x_0 \quad v = at + v_0 \qquad Q = C\Delta T = cm\Delta T = nC_v\Delta T \quad Q_{f,v} = mL_{f,v}$$

$$\Delta E_{int} = Q + W \quad W = \int \vec{F} \cdot d\vec{s} \to P\Delta V \quad \langle \vec{F} \rangle = \frac{\Delta \vec{p}}{\Delta t} \quad P = \frac{|\vec{F}|}{A} \quad PV = Nk_BT = nRT$$

$$\vec{I} = \int \vec{F}dt = \langle \vec{F} \rangle \Delta t = \Delta \vec{p} \quad \langle KE \rangle = \langle E_{kin} \rangle = \frac{1}{2}m\overline{v^2} \quad \langle E_{kin} \rangle = \frac{3}{2}k_BT = \frac{1}{2}mv_{rms}^2 \quad E_{int} = N\langle E_{kin} \rangle = \frac{3}{2}Nk_BT$$

$$v_{rms} = \sqrt{\langle v^2 \rangle} \quad C_V = \frac{f}{2} N_A k_B \quad E_f = \frac{k_B T}{2} \quad E_{int} = \frac{f}{2} N k_B T \quad f \equiv \text{number of degrees of freedom}$$

$$E_{atom} = (n_x + n_y + n_z + \frac{3}{2})\epsilon_i \quad E = \sum_{i=1}^{3N} n_i \epsilon_i = q\epsilon_i \quad \Omega(N,q) = \frac{(q+3N-1)!}{q!(3N-1)!} \quad S = k_B \ln \Omega$$

$$\frac{1}{T} = \frac{dS}{dE} \quad q = \frac{E}{\hbar\omega_0} \quad C = \frac{1}{n}\frac{dE}{dT} \quad E = 3Nk_B T$$

$$\vec{F}_G = -G\frac{m_1 m_2}{r^2}\hat{r} \quad \vec{F}_C = k_e \frac{q_1 q_2}{r^2}\hat{r} \quad \vec{E} \equiv \frac{\vec{F}}{q_0} \quad \vec{E} = k_e \sum_i \frac{q_i}{r_i^2}\hat{r}_i \quad \vec{E} = k_e \int \frac{dq}{r^2}\hat{r} \quad \vec{E}_{dipole} = k_e \frac{q(2a)}{(x^2+a^2)^{3/2}}\hat{j}$$

$$\vec{E}_{ring} = k_e \frac{qx}{(x^2+R^2)^{3/2}}\hat{i} \quad \vec{E}_{plane} = 2\pi k_e \eta \hat{k} = \frac{\eta}{2\epsilon_0}\hat{k} \quad \Delta V \equiv \frac{\Delta PE}{q_0} = -\int_A^B \vec{E}\cdot d\vec{s} \quad V = k_e \frac{q}{r} \quad PE = qV$$

$$V = k_e \sum_n \frac{q_n}{r_n} \quad V = k_e \int \frac{dq}{r} \quad V = Ed \quad I \equiv \frac{dQ}{dt} \quad V = IR \quad P = IV \quad R_{equiv} = \sum R_i$$

The algebraic sum of the potential changes across all the elements of a closed loop is zero.

$$I = nev_d A \quad \vec{F}_B = q\vec{v} \times \vec{B} \quad |\vec{F}_B| = |qvB\sin\theta|$$

$$\frac{dN}{dt} = -\lambda t \quad N = N_0 e^{-\lambda t} \quad t_{1/2} = \frac{\ln 2}{\lambda} \quad y = A\sin(kx - \omega t + \phi) \quad k\lambda = 2\pi = \omega T \quad \frac{\lambda}{T} = c \quad f = \frac{1}{T}$$

$$E = E_m \sin(kx - \omega t) \quad B = B_m \sin(kx - \omega t) \quad \vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B} \quad |\vec{S}| = I = \frac{E^2}{2\mu_0 c} \quad \frac{E_m}{B_m} = c$$

$$I = I_m \cos^2\left(\frac{\pi d}{\lambda}\sin\theta\right) \quad I = I_m \left[\frac{\sin\left(\frac{\pi a}{\lambda}\sin\theta\right)}{\frac{\pi a}{\lambda}\sin\theta}\right]^2 \quad I = I_m \cos^2\left(\frac{\pi d}{\lambda}\sin\theta\right)\left[\frac{\sin\left(\frac{\pi a}{\lambda}\sin\theta\right)}{\frac{\pi a}{\lambda}\sin\theta}\right]^2$$

$$\delta = d\sin\theta = m\lambda \quad \delta = a\sin\theta = m\lambda \quad \phi = k\delta \quad \sin\theta_R = \frac{\lambda}{a} \quad \sin A + \sin B = 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$$

$$L = I\omega = mv_t r \quad I = \sum m_i r_i^2 \quad I = I_{cm} + mR^2 \quad L_0 = L_1 \quad E = \frac{1}{2}mv_r^2 + \frac{L^2}{mr^2} - k_e\frac{e^2}{r}$$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \quad E_n = -\frac{13.6\ eV}{n^2} \quad E = hf = h\frac{c}{\lambda} \quad -\frac{\hbar^2}{2m}\left(\frac{d^2}{dr^2}\right)\Psi(r) + \frac{L^2}{2mr^2}\Psi(r) + V\Psi(r) = E\Psi(r)$$

$$\frac{df(x)}{dx} = \lim_{\Delta x \to 0}\frac{f(x+\Delta x) - f(x)}{\Delta x} \quad \frac{dx^n}{dx} = nx^{n-1} \quad \frac{de^x}{dx} = e^x \quad \frac{df(u)}{dx} = \frac{df}{du}\frac{du}{dx}$$

$$\frac{d}{dx}f(x)\cdot g(x) = f\frac{dg}{dx} + g\frac{df}{dx} \quad \frac{d\ln x}{dx} = \frac{1}{x} \quad \frac{d}{dx}\cos ax = -a\sin ax \quad \frac{d}{dx}\sin ax = a\cos ax$$

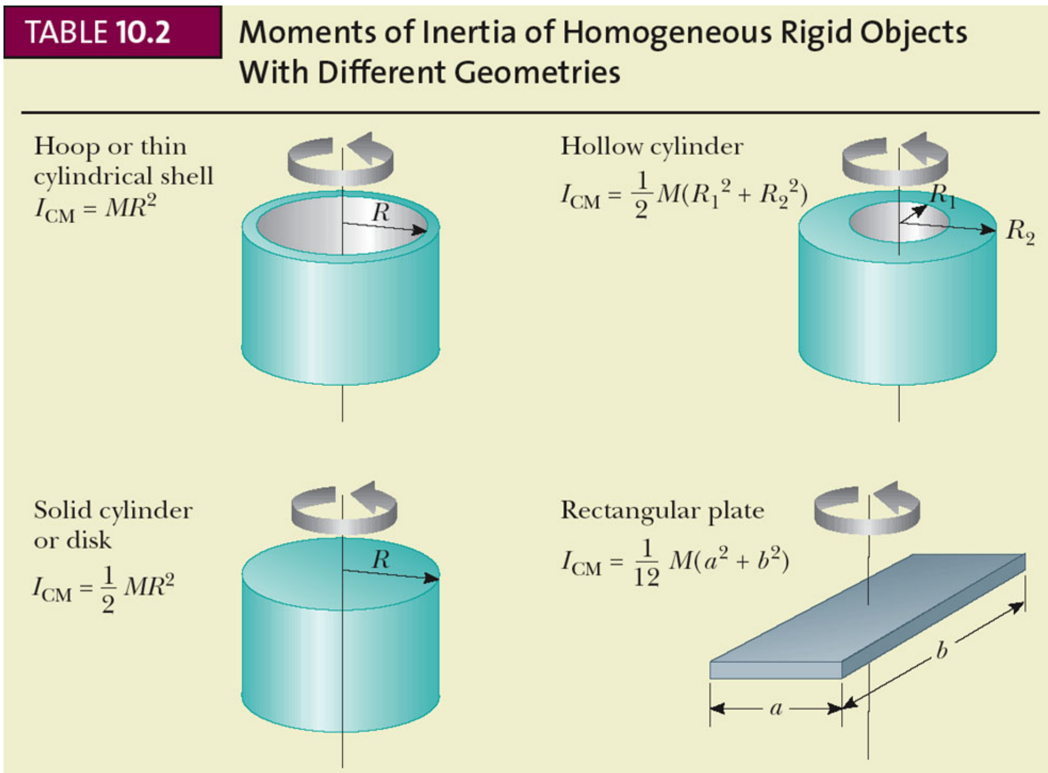
$$\int_a^b f(x)dx = \lim_{\Delta x \to 0}\sum_{n=1}^{N} f(x)\Delta x \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int \sin^2(ax)dx = \frac{x}{2} - \frac{\sin(ax)}{4a}$$

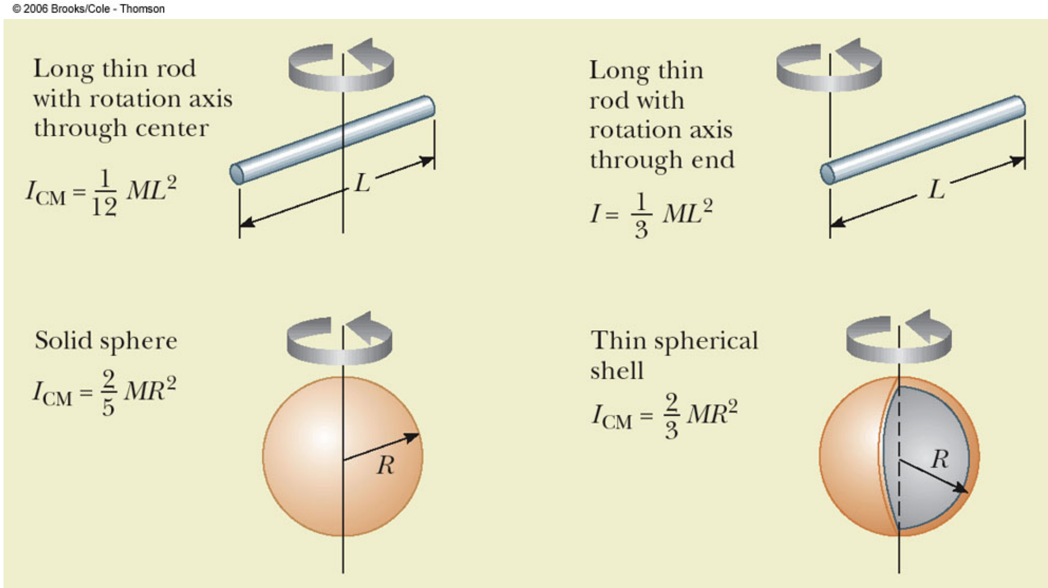
$$\int e^x dx = e^x \quad \int \frac{1}{x}dx = \ln x \int \frac{1}{\sqrt{x^2+a^2}}dx = \ln\left[x + \sqrt{x^2+a^2}\right] \quad \int \frac{x}{\sqrt{x^2+a^2}}dx = \sqrt{x^2+a^2}$$

$$\int \frac{x^2}{\sqrt{x^2+a^2}}dx = \frac{1}{2}x\sqrt{x^2+a^2} - \frac{1}{2}a^2 \ln\left[x+\sqrt{x^2+a^2}\right] \qquad \int \frac{x^3}{\sqrt{x^2+a^2}}dx = \frac{1}{3}(-2a^2+x^2)\sqrt{x^2+a^2}$$

$$\langle x \rangle = \frac{1}{N}\sum_i x_i \quad \sigma = \sqrt{\frac{\sum_i (x_i - \langle x \rangle)^2}{N-1}} \quad N = \frac{b-a}{\Delta x} \quad A = 4\pi r^2 \quad V = Ah \quad V = \frac{4}{3}\pi r^3$$

$$\vec{A}\cdot\vec{B} = AB\cos\theta \quad |\vec{A}\times\vec{B}| = |AB\sin\theta|$$





hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 * *	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

* Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
* * Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

The Periodic Chart.