Useful constants and equations

$e = 1.602 \times 10^{-19}\ C$ $\quad \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9\ N\,m^2/C^2$ $\quad \frac{e^2}{4\pi\epsilon_0} = 1.44\ eV\,nm$

$c = 3.00 \times 10^8\ m/s$ $\quad h = 6.626 \times 10^{-34}\ J\,s = 4.136 \times 10^{-15}\ eV\,s$ $\quad \hbar = \frac{h}{2\pi}$

$hc = 1240\ eV\,nm$ $\quad \hbar c = 197.3\ eV\,nm$ $\quad 1\ eV = 1.602 \times 10^{-19}\ J$ $\quad R_\infty = 1.097 \times 10^7\ m^{-1}$

$m_e = 9.11 \times 10^{-31}\ kg = 511\ keV/c^2 = 5.486 \times 10^{-4}\ u$ $\quad$ neutral ${}^{12}_{6}$C atom mass = 12.0000 u

$m_p = 1.673 \times 10^{-27}\ kg = 938.3\ MeV/c^2 = 1.0073\ u$ $\quad 1\ u = 931.5\ MeV$

$m_n = 1.675 \times 10^{-27}\ kg = 939.6\ MeV/c^2 = 1.0087\ u$

$a_0 = 0.0529\ nm$ $\quad E_0 = -13.6\ eV$ $\quad \alpha = 1/137$

Heisenberg: $\quad \Delta p_x\, \Delta x \sim \hbar \qquad \Delta E\, \Delta t \sim \hbar$

Atomic Physics:

Rutherford Scattering: $$N(\theta) = k \left(\frac{z \cdot Z}{2K_e}\right)^2 \left(\frac{e^2}{4\pi\epsilon_0}\right)^2 \frac{1}{\sin^4(\theta/2)} \quad \text{with} \quad k(=\text{const}) \propto nt$$

θ = scattering angle $\quad n$ = particle density $\quad$ and $\quad t$ = foil thickness

Hydrogen Atom: $$E = \frac{-13.6\ eV}{n^2} \quad \text{with} \quad n = 1, 2, 3, \cdots \quad l < n \qquad -l \le m \le +l$$

Generalized Balmer Formula: $$\frac{1}{\lambda} = R_\infty \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Angular Momentum: $$L^2 = l(l+1)\,\hbar^2 \qquad l = 0, 1, 2, 3, .. \quad \text{(orbital)}$$

$$L_z = \left|\vec{L}\right| \cos\theta = m\,\hbar \qquad -l \ \le\ m_l \ \le\ l \quad \text{(integer steps)}$$

Magnetic Moment: orbital: $$\vec{\mu} = \frac{q}{2\,M} \vec{L}$$

for electron: $$|\mu_z| = 2 \cdot |m_s|\ \frac{e\hbar}{2\,m_e} = \mu_B = 5.8 \times 10^{-5} eV/T$$

for proton: $$|\mu_z| = |m_s|\ \frac{e\hbar}{2\,m_p} = \frac{1}{2}\ \mu_p = \frac{1}{2}\ (8.8 \times 10^{-8} eV/T)$$

Energy of magnetic dipole in B field: $$E = -\mu \cdot B$$

Energy of particle in 3-dim ∞ square well: $$E_{n_x n_y n_z} = \frac{(n_x^2 + n_y^2 + n_z^2) h^2}{8mL^2}$$

Molecular excitations: vibrational: $E = (n + \frac{1}{2})\,\hbar\omega$ $\quad$ rotational: $E = \frac{L^2}{2\,I} = \frac{l(l+1)}{2\,I}\,\hbar^2$

Statistical Physics:

Maxwell Boltzmannc distribution: $f_{MB} = A\, e^{-E/kT}$

Bose-Einstein distribution: $f_{BE} = \dfrac{1}{B\, e^{E/kT} - 1}$

Fermi - Dirac distribution: $f_{FD} = \dfrac{1}{e^{(E-E_F)/kT} + 1}$

Boltzmann constant $k = 1.381 \times 10^{-23}\ J/K = 8.617 \times 10^{-5}\ eV/K$

For "gas" of free fermions: $g(E) = \dfrac{8\sqrt{2}\pi m^{3/2}}{h^3}\sqrt{E}$

$$E_F = \frac{h^2}{2m}\left(\frac{3N}{8\pi V}\right)^{2/3} \qquad\qquad E_m = \frac{3}{5}\, E_F$$

Nuclear Physics:

nuclear radius: $R = (1.2 \times 10^{-15}\, m)\, A^{1/3}$ average binding energy / nucleon $\approx 8\ MeV$

range of interaction: $R = \dfrac{\hbar}{mc} = \dfrac{\hbar c}{mc^2}$

Decay law: $N = N_0\, e^{-\frac{t}{\tau}}$ with $< t >= \tau = \dfrac{1}{\lambda}$ and $T_{1/2} = \dfrac{\ln 2}{\lambda}$

Binding energy B(Z,A) = [Z m_p + N m_n − M_{atom}(Z,A)] c^2

Particle Physics:

Baryon: $Q\,Q\,Q$ Meson: $Q\,\overline{Q}$

Quarks: $\begin{pmatrix} u \\ d \end{pmatrix}\begin{pmatrix} c \\ s \end{pmatrix}\begin{pmatrix} t \\ b \end{pmatrix}\ \begin{matrix} q = +\frac{2}{3} \\ q = -\frac{1}{3} \end{matrix}$ Leptons: $\begin{pmatrix} e \\ \nu_e \end{pmatrix}\begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix}\begin{pmatrix} \tau \\ \nu_\tau \end{pmatrix}\ \begin{matrix} q = -1 \\ q = 0 \end{matrix}$

Cosmology:

Luminosity of star: $L = 4\pi r^2 f^2$ with f = apparent brightness of star

difference in apparent magnitude: $m_1 - m_2 = 2.5\log(f_1/f_2)$