Formula Sheet

$$-\frac{dE}{dx} = \left(\frac{e^2}{4\pi\epsilon_0}\right)^2 \frac{4\pi z^2 N_A Z\rho}{m_e c^2 \beta^2 A}\left[\ln\left(\frac{2m_e c^2\beta^2}{I}\right) - \ln(1-\beta^2) - \beta^2\right]$$

$$-\left(\frac{dE}{dx}\right)_c = \left(\frac{e^2}{4\pi\epsilon_0}\right)^2 \frac{2\pi z^2 N_A Z\rho}{m_e c^2\beta^2 A}\left[\ln\frac{T(T+2m_e c^2)^2\beta^2}{2I^2 mc^2} + (1-\beta^2)\ -(2\sqrt{1-\beta^2}-1+\beta^2)\ln 2 + \frac{1}{8}(1-\sqrt{1-\beta^2})^2\right]$$

$$-\left(\frac{dE}{dx}\right)_r = \left(\frac{e^2}{4\pi\epsilon_0}\right)^2 \frac{Z^2 N_A (T+m_e c^2)\rho}{137\, m_e^2 c^4 A}\left[4\ln\frac{2(T+m_e c^2)}{mc^2} - \frac{4}{3}\right], \qquad \frac{dE}{dx} = \left(\frac{dE}{dx}\right)_c + \left(\frac{dE}{dx}\right)_r$$

$$P(\theta) \approx \tfrac{2\theta}{\langle\theta^2\rangle} e^{-\theta^2/\langle\theta^2\rangle}\, d\theta, \qquad R(E) = R_0(E_{min}) + \int_E^{E_{min}} \left(\frac{dE}{dx}\right)^{-1} dE, \qquad \Delta x = \int_{E-\Delta E}^{E}\left(\frac{dE}{dx}\right)^{-1} dE$$

$$T_e = E_\gamma - B_e, \qquad \sigma = 4\alpha\sqrt{2}Z^5\left(\frac{8\pi r_e^2}{3}\right)\left(\frac{m_e c^2}{h\nu}\right)^{7/2}.$$

$$E'_\gamma = \frac{E_\gamma}{1+(E_\gamma/mc^2)(1-\cos\theta)}, \qquad E'_\gamma = \frac{E_\gamma}{1+(2E_\gamma/mc^2)}$$

$$\sigma = \frac{\pi r_0^2}{\alpha}\left\{\left[1-\frac{2(\alpha+1)}{\alpha^2}\right]\ln(2\alpha+1) + \frac{1}{2}\ + \frac{4}{\alpha} - \frac{1}{2(2\alpha+1)^2}\right\}$$

$$\frac{d\sigma}{d\Omega} = r_0^2\left[\frac{1}{1+\alpha(1-\cos\theta)}\right]^3\left[\frac{1+\cos\theta}{2}\right]\left[1+\frac{\alpha^2(1-\cos\theta)^2}{(1+\cos^2\theta)[+\alpha(1-\cos\theta)]}\right]$$

$$E_\gamma = T_+ + T_- + m_{e^+}c^2 + m_{e^+}c^2$$

$$d\sigma = 4Z^2 r_e^2\alpha\frac{dE_+}{(\nu)^3}\left\{(E_+^2+E_-^2)\left[\frac{\phi_1(\xi)}{4} - \frac{1}{3}\ln Z - f(Z)\right]\ -\frac{2}{3}\varepsilon\left[\frac{\phi_2(\xi)}{4} - \frac{1}{3}\ln Z - f(Z)\right]\right\}, \qquad \xi = \frac{100 m_e c^2 h\nu}{E_+ E_- Z^{1/3}}.$$

$$\sigma_\gamma = \sigma_{PE} + \sigma_{CE} + \sigma_{PP}, \qquad \mu = \sigma_\gamma n Z, \qquad n = \frac{\rho}{\mathcal{M}} N_A, \qquad I = I_0 e^{-\mu t}$$

$$\beta c = v > c/n, \qquad \cos\theta_C = \frac{1}{\beta n(w)}, \qquad \frac{d^2E}{d\omega d\Omega} = z^2\frac{\alpha\hbar}{c} n\beta^2\sin\theta\left|\frac{\omega L}{2\pi\beta c}\frac{\sin\xi(\theta)}{\xi(\theta)}\right|^2, \qquad \xi(\theta) = \frac{\omega L}{2\beta c}(1-\beta\cos\theta).$$

$$-\frac{dE}{dx} = z^2\frac{\alpha\hbar}{c}\int\omega\, d\omega\left(1-\frac{1}{\beta^2 n^2(\omega)}\right).,\qquad \frac{1}{L_{rad}} \simeq \left[4Z(Z+1)\frac{\rho N_A}{A}\right] r_e^2\alpha[\ln(183Z^{-1/3}) - f(Z)]$$

$$N \simeq 2^t, \qquad E(t) \simeq \frac{E_0}{2^t}, \qquad E(t_{max}) = \frac{E_0}{2^t_{max}} = E_c, \qquad t_{max} = \frac{\ln\frac{E_0}{E_c}}{\ln 2}, \qquad N_{max} = \frac{E_0}{E_c}.$$

$$\frac{E'}{E} = \frac{A^2+1+2A\cos\theta}{(A+1)^2}, \qquad \left(\frac{E'}{E}\right)_{\min} = \left(\frac{A-1}{A+1}\right)^2, \qquad \xi = \log\left[\frac{E'}{E}\right]_{\text{av}} = 1 + \frac{(A-1)^2}{2A}\log\frac{A-1}{A+1}$$

$$\log E'_n = \log E - n\xi, \qquad f(E)dE = \frac{2\pi n}{(\pi kT)^{3/2}} E^{1/2} e^{-E/kt} dE, \qquad I = I_0 e^{-\sigma_t n x}$$

$$\sigma(r) = \sqrt{6Dt}, \qquad R = NC\int n(v)\, dv = NCn, \qquad (E_R)_{\max} = E\frac{4A}{(A+1)^2}$$

$$P(t)dt = \mu e^{-\mu t} dt, \qquad P(n) = \frac{\overline{n}^n e^{-\overline{n}}}{n!}, \qquad \sigma = \sqrt{\overline{n}}, \qquad R = 2.35\sqrt{\frac{Fw}{\Delta E}}$$

$$Z_\alpha = 2, \qquad Z_{Au} = 79, \qquad \frac{e^2}{4\pi\epsilon_0} = 1.44 \text{ MeV.fm}, \qquad \hbar c = 197 \text{ MeV.fm}$$

$$m_X c^2 + T_X + m_a c^2 + T_a = m_Y c^2 + T_Y + m_b c^2 + T_b, \qquad Q = (m_X + m_a - m_Y - m_b)c^2 = T_Y + T_b - T_X - T_a$$

$$T_b^{1/2} = \frac{m_a m_b T_a)^{1/2} \cos\theta \pm \{m_a m_b T_a \cos\theta + (m_Y + m_b)[m_Y Q + (m_Y - m_a)T_a]\}^{1/2}}{m_Y + m_b}$$

$$T_{th} = (-Q)\frac{m_Y + m_b}{m_Y + m_b - m_a}, \qquad Q_{ex} = Q_0 - E_{ex}, \qquad \frac{d\sigma}{d\Omega} = \frac{r(\theta,\phi)}{4\pi I_a N}, \qquad \sigma = \int \frac{d\sigma}{d\Omega}\, d\Omega$$

$$r(\theta,\phi) = 4\pi I_a N \frac{d\sigma}{d\Omega}\Delta\Omega, \qquad r = I_a N \sigma, \qquad N = \rho \frac{N_A}{\mathcal{M}} t$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{z^2 Z^2 e^2}{4\pi\epsilon_0}\right)\left(\frac{1}{4T_a}\right)^2 \frac{1}{4\sin^4(\theta/2)}, \qquad r = r_0 A^{1/3}, \qquad r_0 = 1.7 \text{ fm}, \qquad \lambda = h/p$$

$$1\text{u} = 1.6605 \times 10^{-27}\text{kg} = 931.5\text{MeV}$$

$$\frac{d\sigma}{d\Omega} \propto \left| \int e^{i\mathbf{k}_{out}.\mathbf{r}} V(\mathbf{r}) e^{-i\mathbf{k}_{in}.\mathbf{r}}\, dV \right|^2, \qquad q = 2k\sin\theta/2, \qquad \frac{d\sigma}{d\Omega}(\theta) \propto \left| \int e^{i\mathbf{q}.\mathbf{r}} V(\mathbf{r})\, dV \right|^2$$

$$\frac{d\sigma}{d\Omega}(\theta) \propto \left| \frac{1}{q^2} \int \sin qr' \rho(r')\, dr' \right|^2, \qquad \sigma = \frac{\pi}{k^2}(2l+1)\frac{\Gamma^2}{(E - E_R)^2 + \Gamma^2/4}$$

$$E_{max} = \frac{Q}{4\pi\epsilon_0 R_{min}^2}, \qquad V_{max} = \frac{Q}{4\pi\epsilon_0 R_{min}}, \qquad R_{min} = \frac{V_{max}}{E_{max}}$$

$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B}), \qquad E = neV, \qquad E = (n+1)eV, \qquad F = \frac{mv^2}{r}$$

$$\nu = \frac{qB}{2\pi m}, \qquad T_{max} = \frac{q^2 B^2 R_{max}^2}{2m}, \qquad mv = \gamma m_0 v = (1 - v^2/c^2)^{1/2} m_0 v, \qquad K = \frac{e^2 B^2 R^2}{2m_p}, \qquad T = \frac{Kz^2}{A} \text{ MeV}$$

$$E = \sqrt{p^2c^2 + m^2c^4} = \sqrt{e^2r^2B^2c^2 + m^2c^4}, \qquad \nu = \frac{eBc^2}{2\pi\sqrt{e^2r^2B^2c^2 + m^2c^4}}$$

$$L_n = \nu_n t/2, \qquad T_n = neV_0, \qquad L_n = \left(\frac{neV_0}{2m}\right)^{1/2} t$$