PCS229 Formula Sheet

Units & Constants

Radio Decay

$1eV = 1.6 \times 10^{-19} J$
$m_{nucleon} = 1.67 \times 10^{-27} kg$
$m_{electron} = 9.11 \times 10^{-31} kg$
$M_H = 1.007825u$
$M_n = 1.008665u$
$M_e = 0.00055u$
$1amu = 1.4924 \times 10^{-10} J = 931.5MeV$
$1Ci = 3.7 \times 10^{10} Bq$
$1b = 10^{-24} cm^2 = 10^{-28} m^2$

Radiation Interactions

$w_{air} = 33.85eV/ion\ pair$
$E_\beta = 0.511MeV$
$1R = 2.58 \times 10^{-4} C/kg\ air$

Dose

$1Gy = 100rad = 1J/kg$
$1Sv = 1J/kg = 1Gy$
$1Sv = 100rem$
$Risk/Dose = 5 \times 10^{-4}/rem = 5 \times 10^{-6}/Sv$

Radioactive Decay

$^{235}_{92}\text{U} = ^{A}_{Z}\text{X}$
$r \approx (1.2 \times 10^{-15}) A^{1/3}$
$\rho = \frac{m_{nucleon}}{\frac{4}{3}\pi(1.2\times10^{-15})}$
$E_B = \Delta m \times amu = (Zm_H + (A - Z)M_n - M_{element}) \times (\frac{931MeV}{1amu})$
$^{A}_{Z}\text{P} \rightarrow ^{A-4}_{Z-2}\text{D} + ^{4}_{2}\text{He}$
$Q = M_P - M_D - M_{He} - 2M_e$
$^{A}_{Z}\text{P} \rightarrow _{Z+1}^{\ \ A}\text{D} + ^{\ \ 0}_{-1}\beta^- + ^{0}_{0}\bar{v}$
$^{A}_{Z}\text{P} \rightarrow _{Z+1}^{\ \ A}\text{D} + ^{0}_{1}\beta^+ + ^{0}_{0}v + e^-$
$E_{\beta eff} \approx \frac{1}{3} E_{max}$
$^{A}_{Z}\text{P} + ^{\ \ 0}_{-1}e^- \rightarrow _{Z-1}^{\ \ A}\text{D} + ^{0}_{0}v$
$^{A}_{Z}\text{P}^* \rightarrow ^{A}_{Z}\text{P} + \gamma$
$^{A}_{Z}\text{P}^* \rightarrow ^{A}_{Z}\text{P}^+ + e^- + Q_{IC} \rightarrow ^{A}_{Z}\text{P}$
$\alpha_{IC} = \frac{P(IC)}{P(\gamma)} = \frac{N_{IC}}{N_\gamma}$
$p \rightarrow \alpha < \beta < \gamma$
$i \rightarrow \alpha > \beta > \gamma$
$\frac{\Delta N}{\Delta t} = -\lambda N = -\frac{ln(2)}{T_{1/2}} N = \frac{dN}{dt}$
$\tau = \frac{1}{\lambda}, N = N_0 e^{-\lambda t}, A = \lambda N = A_0 e^{-\lambda t}$
$D = P_0 \frac{\lambda_P}{\lambda_D - \lambda_P}(e^{-\lambda_P t} - e^{-\lambda_D t})$
for $T_{1/2}(P) >> T_{1/2}(D)$, $\frac{D\lambda_D}{P\lambda_P} \approx \frac{\lambda_D}{\lambda_D - \lambda_P}$
for $T_{1/2}(P) << T_{1/2}(D)$, $\frac{D\lambda_D}{P\lambda_P} \approx (1 - e^{-\lambda_D t})$
$N(t) = \frac{K}{\lambda}(1 - e^{-\lambda t})$
$N(t) = \phi\rho\theta \frac{mNa}{M} \frac{1}{\lambda}(1 - e^{-\lambda t})$
for $t << T_{1/2}, N(t) = \phi\rho\theta \frac{mN_A}{M} t$
for $t >> T_{1/2}, N(t) = \phi\rho\theta \frac{mN_A}{M} \frac{1}{\lambda}$

Radiation Interactions

$-\frac{dE}{dx} = \mu Q_{max}$
Bethe stopping power
$-\frac{dE}{dx} = \frac{4\pi e^4 z^2 \rho Z}{m_e}\left[ln\frac{2m_e v^2}{I} - ln(1-\beta^2) - \beta^2\right]$
$S = \frac{dE/dx}{\rho}$ $LET = \frac{dE_L}{dl}$
$-\frac{dE}{dx} = (w)(Specific\ Ionization)$
$\rho_m = \frac{S_{medium}}{S_{air}}$
for $0.01MeV < KE_{max} < 3MeV$,
$R = 412(T_{\beta max})^{1.265 - 0.0954 ln(T_{\beta max})}$
for $1MeV < KE_{max} < 20MeV$,
$R = 530(T_{\beta max}) - 106$
$E_{electron} = E_\gamma - E_B = h\nu - E_B$
$E'_\gamma = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_0 c^2}(1 - cos\theta)}, E_\gamma > 2m_0 c^2$
$\lambda' = \lambda + \frac{h}{m_0 c}(1 - cos\theta)$

Radiation Dose

$\phi = \frac{N}{A}, \varphi = \frac{\phi}{t}$
$\Psi = \phi E, \psi = \varphi E = I$
$D = \frac{E_{absorbed}}{m}$, RBE Dose $D \times RBE$
$H_T = \sum_R w_R D_{T,R}, H_E = \sum_T w_T H_T$
$E \propto f(\frac{t}{r^2})$

Radiation	Q
X, γ, β	1
Neutrons	
Thermal	2
0.01 MeV	2.5
0.1 MeV	7.5
0.5 MeV	11
Unknown Energy	10
High-energy protons	10
α particles, fission fragments, heavy nuclei	20

Organ	w_T
Gonads	0.20
Colon	0.12
Bone Marrow	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Chest	0.05
Liver	0.05
Thyroid	0.05
Skin	0.01
Bone Surface	0.01
Adrenals, brain, small intestine, kidney, muscle, pancreas, spleen, thymus, uterus	0.05

Radiography, Nuclear Medicine, Imaging

$\lambda_0 = \frac{hc}{eV}, I = I_0 e^{-\mu x}$
$CT = 1000\left(\frac{\mu_i - \mu_w}{\mu_w}\right)$
$I = I_0 e^{-(\frac{\mu}{\rho})\rho x}$
$Risk = D \times (Risk\ per\ dose)$
$R = (L + z)tan\theta = s\left(1 + \frac{z}{L}\right)$
$v = \sqrt{\frac{B}{\rho}}, B = \frac{\Delta P}{\Delta V/V}, p = I_{instant} = \frac{p^2}{\rho v}$
$X = \frac{\Gamma A t}{d^2}$
$\frac{\overline{UA}}{(SSD - SDD)} = \frac{\overline{S_1 S_2}}{SDD}$