Isotope Separation

$$SWU = [PV(x_p) + WV(x_w) - FV(x_f)]\,\tau \text{ [kg-SWU]} \quad (1)$$

$$\frac{F}{P} = \frac{x_p - x_w}{x_f - x_w} \qquad \frac{W}{P} = \frac{x_p - x_f}{x_f - x_w} \quad (2)$$

$$V(x_i) = (2x_i - 1)\ln\left(\frac{x_i}{1 - x_i}\right) \text{ SWU} \quad (3)$$

$$N = \frac{2}{\ln\alpha}\ln\left[\frac{x_p\,(1 - x_w)}{x_w\,(1 - x_p)}\right] - 1 \quad (4)$$

$$\alpha = \sqrt{\frac{m_H}{m_L}} \quad (5)$$

$$\alpha = exp\left[\frac{(m_H - m_L)\,\omega^2 r^2}{2RT}\right] \quad (6)$$

Fissioning Sphere

$$k_\infty = \nu\frac{\Sigma_f}{\Sigma_a} = \nu\frac{\sigma_f}{\sigma_a} \quad k = k_\infty L \quad (7)$$

$$l_\infty = \frac{\lambda_a}{v} = \frac{1}{\Sigma_a v} \quad l = l_\infty L \quad (8)$$

$$\alpha = \frac{k - 1}{l} \quad (9)$$

$$n(t) = n_0 e^{\alpha t} \quad Y(t) = \frac{\Sigma_f v Q n_0}{\alpha}\left(e^{\alpha t} - 1\right) \quad (10)$$

Weapon Mechanics

$$\left(\frac{Y}{3}\right) = \frac{1}{2}M\,(u_2)^2 \quad (11)$$

$$\Sigma = \Sigma_0\frac{\rho}{\rho_0}\left[1 - BF + 2BF\frac{\sigma_{ff}}{\sigma_{fuel}}\right] \quad (12)$$

Fusion

$$Y = Number_{reactions} \times Q \quad (13)$$

$$Y = \frac{4}{3}\pi R^3\; n_{tar}\; Q \quad (14)$$

$$N_{reac} = (\overline{\sigma v})\,n_{tar} n_{bomb} \quad n_{tar} = n_{bomb} = \frac{n_{tot}}{2} \quad (15)$$

$$(\overline{\sigma v})_{DD} = 2.33 \times 10^{-14} E^{-\frac{2}{3}} e^{-18.76E^{\frac{-1}{3}}} \quad (16)$$

$$(\overline{\sigma v})_{DT} = 3.68 \times 10^{-12} E^{-\frac{2}{3}} e^{-19.94E^{\frac{-1}{3}}} \quad (17)$$

$$R_{SB} \geq \frac{3\sigma_{sb}T^4}{n_b n_t\,(\overline{\sigma v})\,Q_l} \quad (18)$$

Weapons Effects

X-Ray Effects

$$S_x(h\nu) = Y_{ST}P(h\nu, T_{ST}) + Y_{RR}P(h\nu, T_{RR}) \quad (19)$$

$$F(r) = \frac{Y_x}{4\pi r^2} \qquad Y_x = 0.7Y \quad (20)$$

$$P_g = \int_{h\nu_{g-1}}^{h\nu} \frac{15}{(\pi kT)^4}\left[\frac{(h\nu)^3}{exp\left(\frac{h\nu}{kT}\right) - 1}\right] d(h\nu) \quad (21)$$

$$E_{dep}(x) = \sum_{g=1}^{G}\left[P_g F_0 e^{(-\mu_g x)}\left(\frac{\mu_a}{\rho}\right)_g\right] \quad (22)$$

$$p(x) = E_{dep}(x)\rho_0 \quad (23)$$

Fireball Growth

$$R \approx 90W^{0.4} \quad R \approx 100W^{0.4} \quad R \approx 145W^{0.4} \quad H \approx 180W^{0.4} \quad (24)$$

Thermal

$$P_{max} \approx 3.18W^{0.56}\text{ kT/s} \quad t_{max} \approx 0.0417W^{0.44}\text{ s} \quad (25)$$

$$P_{max} = \frac{3.56W^{0.59}}{[\rho(h)/\rho_0]^{0.45}}\text{ kT/s} \quad t_{max} = 0.038W^{0.44}[\rho(h)/\rho_0]^{0.36}\text{s} \quad (26)$$

$$E_{tot} = fW \quad (27)$$

$$Q\left(\frac{cal}{cm^2}\right) = \frac{10^{12} fW\tau}{4\pi D^2[\text{cm}]} \quad (28)$$

$$Q\left(\frac{cal}{cm^2}\right) \approx \frac{85.6fW\tau}{D^2[\text{kft}]} \quad (29)$$

$$Q\left(\frac{cal}{cm^2}\right) \approx \frac{3.07fW\tau}{D^2[\text{miles}]} \quad (30)$$

Blast and Shock

$$\frac{D}{D_1} = \left(\frac{W}{W_1}\right)^{\frac{1}{3}} \quad D = D_1 \times W^{\frac{1}{3}} \quad (31)$$

$$d = d_1 \times W^{\frac{1}{3}} \quad t = t_1 \times W^{\frac{1}{3}} \quad h = h_1 \times W^{\frac{1}{3}} \quad (32)$$

$$S_p = \frac{P}{P_0} \quad S_d = \left(\frac{P_0}{P}\right)^{\frac{1}{3}} \quad S_t = \left(\frac{P_0}{P}\right)^{\frac{1}{3}}\left(\frac{T_0}{T}\right)^{\frac{1}{2}} \quad (33)$$

$$p = p_1 S_p \quad D = D_1 W^{\frac{1}{3}} S_d \quad d = d_1 W^{\frac{1}{3}} S_d \quad t = t_1 W^{\frac{1}{3}} S_t \quad (34)$$

Underground

$$DOB_1 = \frac{DOB}{W^{0.3}} \quad R_a \approx R_{a1}W^{0.3} \quad D_a \approx D_{a1}W^{0.3} \quad (35)$$

$$V = \frac{1}{2}\pi R_a^2 D_a \quad (36)$$

$$R_{al} = 1.25R_a\; D_{al} = 1.25D_a\; H_{al} = 0.25D_a\; R_e = 2.15R_a \quad (37)$$

Initial Radiation

$$D = D_n + D_{\gamma s} + D_{\gamma f} \quad H = DQ \tag{38}$$

Residual Radiation

$$R_t \approx R_1 t^{-1.2} \tag{39}$$

$$D \approx R_1 \int_{t_a}^{t_b} t^{-1.2} dt \quad D \approx 5R_1 \left(t_a^{-0.2} - t_b^{-0.2}\right) \tag{40}$$

Radiation Interactions

$$H = DQ \text{ [rem]} \tag{41}$$

$$I = I_0 e^{-\mu x} \tag{42}$$

$$\frac{\mu}{\rho} = \frac{1}{100}\left(\sum_{n=1}^{i} \omega_i \left(\frac{\mu}{\rho}\right)_i\right) \left[\frac{\text{cm}^2}{\text{g}}\right] \tag{43}$$

$$\mu = N\sigma \qquad \lambda = \frac{1}{\mu} \tag{44}$$

$$N = \frac{\rho N_A}{M} \qquad \Sigma = N\sigma \tag{45}$$

Constants and Conversions

Avg ^1n speed in weapon assembly $v = 1.08 \times 10^9 \frac{cm}{s}$

1 kT=4.186×10^{12} J

1 kT=2.613×10^{25} MeV

1 kT=0.9993×10^{12} cal

1 J=6.241457×10^{18} eV

1 ev=1.1605×10^4 K

R = 8.31 $\frac{J}{mol \cdot K}$

$\sigma_{sb} = 5.670 \times 10^{-8}$ $\frac{\text{J}}{\text{K}^4\text{m}^2\text{s}}$

Avg ^1n microscopic cross sections for "fast spectrum" neutrons (barns)

Isotope/ Element	scatter σ_s	inelastic σ_{in}	absorption σ_a	Production xsec $\nu\sigma_f$	transport σ_{tr}	avg. neutrons ν
Fission Fragments	5.00	0.562	0.0711	0.0	5.63	-
^{232}Th	6.52	1.51	0.157	0.112	6.10	2.45
^{233}U	4.84	0.678	2.09	5.17	5.40	2.72
^{235}U	5.33	1.25	1.44	3.32	5.99	2.60
^{238}U	6.17	1.97	0.271	0.415	6.30	2.82
^{239}Pu	5.72	0.851	1.98	5.61	6.60	2.98
^{241}Pu	5.65	1.13	1.79	5.39	6.74	2.95

Average Energy Released in Fission

Energy Form	^{235}U	^{239}Pu
Fission Fragment Kinetic Energy	168	172
Neutron Kinetic Energy	6	7
Prompt Gamma Energy	7	7
TOTAL PROMPT ENERGY (MeV)	180	185
Delayed Beta Energy	8	8
Delayed Gamma Energy	7	7
Anti-neutrinos	12	12
Total Delayed Energy (MeV)	25	25
Total Fission Energy (MeV)	207	212

Properties of select Thermonuclear Reactions

	Reaction	Q-Value (MeV)	TNT Equivalent (kT per 1 kg)
1	H+H→D+$^0_1$e	1.11	16.5
2	H+D→$^3_2$He	5.50	41.8
3	H+T→$^4_2$He	19.81	113.0
4*	D+D→T+H	4.03	23.0
5*	D+D→$^3_2$He+$^1_0$n	3.27	18.7
6*	D+T→$^4_2$He+$^1_0$n	17.6	80.6
7	$^3_2$He+D→$^4_2$He+H	18.3	83.5
8	T+T→$^4_2$He+2×$^1_0$n	11.3	43.1
9	$^6_3$Li+D→2×$^4_2$He	22.4	64.2
10	$^6_3$Li+T→$^4_2$He+$^1_0$n	16.1	41.0
11	$^7_3$Li+H→2×$^4_2$He	17.3	50.0
12	$^{11}_5$B+H→3×$^4_2$He	8.7	16.5

*$Q_{DD} = 9.96\,MeV$

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