7/1

Energy & the Environment

Homework #7 Ch18: 31, 36, 41, 44
19: 31, 34, 41
20: 34, 36
} 90 pts. total

(18.31) Find Binding energy of $^{2}_{1}H$

$^{2}_{1}H$ ← 1 neutron, 1 proton

from Fig 18.4, Average binding energy = 1.2 MeV/nucleon

$$\text{Binding energy} = 1.2 \frac{\text{MeV}}{\text{nucleon}} * 2\text{ nucleons}$$

$$^{2}_{1}H \text{ Binding Energy} = 2.4 \text{ MeV}$$

from wikipedia, nuclear mass of $^{2}_{1}H$ =

(3) 2.01355321270 u

(1) proton mass = 1.007276470 u

(2) neutron mass = 1.008664904 u

Mass defect = (1) + (2) − (3) =

= .002388162 u

$E = mc^2$ = Binding energy = .002388162 $(1.66053873 \times 10^{-27} \text{ kg})$ ↓

$$* (3.\times10^{8})^{2} = 3.57\times10^{-13}\,J = \text{Binding Energy}$$

$$= \frac{3.57\times10^{-13}\,J}{1.602176\times10^{-19}\,J/eV}$$

Binding Energy = 2.228 meV

(18.36) Find binding energy from Fig. 18.4 $^{238}_{94}Pu$ $\simeq$ 7.5 meV/nucleon

Find conversion factor between u & meV

$$= \frac{(1.660539\times10^{-27})(3\times10^{8})^{2}\,J/u}{(1\times10^{6}\,\frac{eV}{meV})(1.602176\times10^{-19}\,\frac{J}{eV})} = 932.8\,\frac{meV}{u}$$

$$\left(\frac{meV}{nucl.}\right)\text{Binding energy} = \frac{\left(144(1.008665)+94(1.007276)-238.0496\ u\right)932.8\,\frac{meV}{u}}{238\ \text{nucleons}}$$

$$^{238}_{94}Pu\ \text{Binding Energy} = 7.38\,\frac{meV}{\text{nucleon}}$$

Hwk #7 (7/3)

(18.41)

$n + {}^{239}_{94}Pu \rightarrow {}^{240}_{94}Pu \rightarrow {}^{100}_{44}Ru + {}^{134}_{50}Sn + 6n$

+ energy

${}^{240}_{94}Pu$: $240(7.5) = 1800$ meV

${}^{100}_{44}Ru$: $100(8.3) = 830$ meV

${}^{134}_{50}Sn$: $134(8.3) = 1112$ meV

BE(mEV) = $1112 + 830 - 1800$

Energy Released = 142 meV

(18.44) ${}^{247}_{97}Bk \rightarrow {}^{243}_{95}Am + {}^{4}_{2}He$

a) ${}^{243}_{95}Am$ ← daughter nucleus

b)

$N(t) = N_0 e^{-t/\tau}$ τ = mean life

if $N_0 = 100{,}000$ $t = \tau$

$N(\tau) = 100{,}000\, e^{-1} = 36{,}790$ nuclei remain

c) $N(3\tau) = 100{,}000\, e^{-3}$

$N(3\tau) = 4{,}979$ remain

(19.31)

1000 MW plant @ 33% efficiency

Consumes $3\times10^{9}\,W = \dfrac{3\times10^{9}\,\frac{J}{s}}{1.602\times10^{-19}\,\frac{J}{eV}}$

$= \dfrac{1.873\times10^{28}\,\frac{eV}{s}}{200\times10^{6}\,\frac{eV}{fission}}$

$= 9.365\times10^{19}$ fissions/sec

Amt uranium used $= \dfrac{(9.365\times10^{+19}\text{ fission/sec})(86400\,\frac{s}{d})(235\,\frac{g}{m})}{6.023\times10^{23}}$

Amt uranium used = 3157 g/day = 3.16 kg/d

(19.34) Assume 33% efficiency for coal plant.

Amt Coal used $= \dfrac{(3\times10^{9}\,\frac{J}{s})(86400\,\frac{s}{d})}{(23.4\times10^{6}\,\frac{J}{kg})}$

$= 1.1\times10^{7}\,\dfrac{kg}{day}$

from 19.31 Amt uranium used $= 3.16\,\dfrac{kg}{day}$

19.41 response time $= \frac{\tau}{(K-1)}$

$K = 1 \rightarrow$ critical

$K > 1$ supercritical

$K < 1+f$, f = fraction delayed

For U_{235}, $f = 0.007$

$\tau = .993(10^{-14}) + .007(14)$ sec

$\tau = 9.8 \times 10^{-2}$ sec

$K = 1+f = 1.0 + .007 = 1.007$

response time (sec) $= \frac{9.8 \times 10^{-2} \text{ sec}}{1.007 - 1}$

response time $= 14$ sec

If response time $= RT = \frac{\tau}{(K-1)}$

$RT = \frac{9.8 \times 10^{-2}}{K-1}$

$RT(K) - RT = 9.8 \times 10^{-2}$

$K = \frac{RT + 9.8 \times 10^{-2}}{RT}$

$K = 1.0008$ for $RT = 120$ sec's

$K = 1.0010$ for $RT = 100$ sec

7/6

(20.34) Given 2.5 Sv/hr exposure for 15 hours

Dose = (2.5 Sv/hr)(15 hr) = 37.50 Sv

Dose = 37,500 mSv

1/2 exposed people die @ 3,000-7,000 mSv
> 25,000 most tissue destroyed

(20.36) Co-60 γ rays 1.16 MeV
1/2 life = 5.3 yr 1.30 MeV

Raccoon ingests 2g & excretes it after 32 h

(a) What is the dose?

$$\text{Amt decays after } 32h = 2g\left(1 - \exp\left(\frac{-.693(32h)}{5.3(365)(24h)}\right)\right)$$

$= 9.55 \times 10^{-4}$ g / 60g/mole

$= 1.59 \times 10^{-5}$ mole $*$ 6.023×10^{23} quanta/mole

$= 9.59 \times 10^{18}$ quanta / 6.2415×10^{18} quanta/coulomb

$= 1.536$ C

(b) Energy released = Volt $*$ coulomb

$= \left(\frac{1.16 + 1.30}{2} \text{ MeV}\right)(1.536 \text{ C}) = 1.889 \times 10^{6}$ J

$$\text{Dose} = \frac{\text{Energy Absorbed (J)}}{\text{Body Mass (kg)}}$$

Assume 6kg mass

$$\text{Dose} = \frac{1.89\times10^{6}\,J}{6\,kg} = 3.15\times10^{5}\,\frac{J}{kg}$$

$$= 3.15\times10^{5}\,Gy$$

$$= 3.15\times10^{5}\,Sv$$ for γ rays

at this exposure the raccoon would surely die