10-1

a) $^{14}_{7}N + n \longrightarrow ^{14}_{6}C + \beta^{+}$

b) $^{226}Ra \longrightarrow ^{222}Rn + \alpha$

c) $^{14}_{6}C \longrightarrow ^{14}_{7}N + \beta^{-}$

d) $^{1}_{1}H + 2p \longrightarrow ^{3}_{1}H + 2\beta^{-}$

e) $^{3}_{1}H \longrightarrow ^{3}_{2}He + \beta^{-}$

10-2

$$E = (4-9)\times 10^{6}\ eV \times 1.60\times 10^{-19}\ \frac{J}{eV} = (6.4-14.4)\times 10^{-13}\ J$$

$$E = 1/2\, mv^{2} \quad \therefore \quad v = \sqrt{\frac{2E}{m}}$$

$m = 6.64\times 10^{-27}$ kg [wiki]

$$v = \sqrt{\frac{2\cdot(6.4-14.4)\times 10^{-13}}{6.64\times 10^{-27}}}$$

$$\boxed{v = (1.4\times 10^{7}\ m/s - 2.1\times 10^{7}\ m/s)}$$

10-4

- $^{11}_{5}B$ has 5 protons and $(11-5) = 6$ neutrons
- $^{234}_{90}Ac$ has 90 protons and $(234-90) = 144$ neutrons
- $^{235}_{92}U$ has 92 protons and $(235-92) = 143$ neutrons
- $^{238}_{92}U$ has 92 protons and $(238-92) = 146$ neutrons

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10-7

$$^{115}_{49}In + n \longrightarrow {}^{116}_{49}In$$

10-8

$^{22}Na : t_{1/2} = 2.6\ y$

$^{35}S : t_{1/2} = 87\,d \times \frac{y}{365\,d} = 0.238\ y$

$$\lambda_{Na} = \frac{\ln(2)}{t_{1/2}} = \frac{\ln(2)}{2.6} = 0.267\ y^{-1}$$

$$\lambda_S = \frac{\ln(2)}{t_{1/2}} = \frac{\ln(2)}{0.238} = 2.91\ y^{-1}$$

$$A_{Na} = A_0 e^{-\lambda_{Na} t} \qquad A_S = A_0 e^{-\lambda_S t}$$

$$A_{Na} = 5000\, e^{-\lambda_{Na} t} \qquad A_S = 20000\, e^{-\lambda_S t}$$

$$A_{Na} = A_S$$

$$5000\, e^{-\lambda_{Na} t} = 20000\, e^{-\lambda_S t}$$

$$0.25 = e^{-\lambda_S t} e^{\lambda_{Na} t} = e^{t(\lambda_{Na} - \lambda_S)}$$

$$\ln(0.25) = t(\lambda_{Na} - \lambda_S)$$

$$t = \frac{\ln(0.25)}{\lambda_{Na} - \lambda_S} = 0.523\ y \ \boxed{= 191 \text{ days}}$$

$$A_{Na} = 5000\, e^{-0.267(0.523)} \ \boxed{= 4.35 \times 10^3 \text{ counts/s}}$$

10-12

1.2×10^{21} Bq = atoms/s (lost)

heat = 1.0×10^{6} eV $\times$ $1.6\times10^{-19}\frac{J}{eV}$ = 1.6×10^{-13} J

$\frac{heat}{s}$ = power = $(1.6\times10^{-13})(1.2\times10^{21})$

= 192 MW

- a medium sized power plant.

10-16

a) $\sigma = 0.332\times10^{-24}[m^2]$, $M = 18\,g/mol$, $m = 1000\,g$

$n = \frac{m}{M}N_a = \frac{1000g}{18g/mol}\cdot 6.022\times10^{23}\frac{atoms}{mol}\cdot\frac{2\,H}{1\,H_2O} = 6.69\times10^{25}$

$\Delta N = n\sigma Ft = (6.69\times10^{25})(0.332\times10^{-28})(1\times10^{17})(\frac{3600s}{h}\cdot\frac{24h}{d}\cdot 365)$

$\Delta N = 7.0\times10^{21}$ nuclei

b) $\sigma = 5.2\times10^{-32}[m^2]$ $M = 20g/mol$, $m = 1000\,g$

$n = \frac{1000}{20}\times 6.02\times10^{23}\times\frac{2\,D}{1\,D_2O} = 6.02\times10^{25}$

$\Delta N = (6.02\times10^{25})(5.2\times10^{-32})(1\times10^{17})(3600\times24\times365)$

$\Delta N = 9.9\times10^{18}$ nuclei

c) $\bar{A} = \Delta N\lambda = \frac{\Delta N\ln(2)}{t_{1/2}} = \frac{(9.9\times10^{18})(\ln(2))}{12.3} = 5.6\times10^{17}\,y^{-1}$

$= 1.76\times10^{10}$ Bq

10-19

$$^{239}_{94}Pu + ^{1}_{0}n \longrightarrow ^{240}_{94}Pu$$

BE per nucleon = 7.56 MeV BE per nucleon = 7.556 MeV

$$\Delta BE = (240 \cdot 7.556) - (239 \cdot 7.56)$$

$$\boxed{\Delta BE = 6.60 \text{ MeV}}$$

10-22

$$E = 94 \frac{cal}{mol} \times \frac{4184 \text{ J}}{cal} = 3.93 \times 10^5 [J/mol]$$

$$m = \frac{E}{c^2} = \frac{3.93 \times 10^5}{(3 \times 10^8)^2} = 4.4 \times 10^{-12} \text{ kg/mol}$$

$$^{12}C = \frac{12g}{mol} \times \frac{kg}{1000g} = 0.012$$

$$\% \text{ change} = \frac{4.4 \times 10^{-12} \text{ kg/mol}}{0.012 \text{ kg/mol}} \times 100 \quad \boxed{= 3.7 \times 10^{-8} \%}$$

- very small change!

10-23

- atomic mass = 205.9744 u

predicted mass $^{206}_{82}Pb$ = $82(1.0078252\,u) + 124(1.0086652\,u)$

= 207.7162 u

- excess mass = $(207.7162 - 205.9744)\,u$

= 1.742 u

$$E = 1.742\,u \times 931.5\,\frac{MeV}{u} = 1.622 \times 10^3\ MeV$$

$$\frac{BE}{nucleon} = \frac{E_{excess}}{206} = \frac{1.622 \times 10^3\ MeV}{206} = \boxed{7.877\ MeV}$$

* [wolfram] actual BE/n = 7.875361 MeV

Question #2

Isotopes	Half-life (y)	Activity @ t=0	Activity @ t=2
3H	12.300000	4.90E+14	4.38E+14
85Kr	10.700000	2.80E+16	2.46E+16
89Sr	0.139720	2.70E+18	1.33E+14
90Sr	28.900000	2.00E+17	1.91E+17
90Y	0.007360	2.00E+17	3.16E-65
91Y	0.161000	3.60E+18	6.56E+14
99Mo	0.182500	4.40E+18	2.21E+15
131I	0.022100	3.10E+18	1.77E-09
133Xe	0.014520	6.00E+18	2.06E-23
134Cs	2.060000	6.70E+16	3.42E+16
132Te	0.008904	3.80E+18	9.18E-50
133I	0.056986	2.40E+18	6.53E+07
140Ba	0.035616	5.10E+18	6.36E+01
140La	0.004589	5.40E+18	3.44E-113
144Ce	0.778100	3.90E+18	6.57E+17
Sums	55.371395	4.09E+019	9.09E+017

Q - 3

$$^{115}In + {}^{1}_{0}n \longrightarrow {}^{116}In$$

$m = 10g$

$M_{In} = 114.82 g/mol$

$A_0 = 10^8$ Bq

$t = 10s$

$\sigma = 198$ barns

$t_{1/2} = 54m \times \frac{60s}{m} = 3240s$

$F = FLUX = ?$

$$\Delta N = n \sigma F \quad , \quad n = \frac{m N_A}{M}$$

$$\underline{\underline{\Delta N}} = \frac{m N_A}{M} \sigma F$$

$$A_0 = \lambda \Delta N t \longrightarrow \underline{\underline{\Delta N}} = \frac{A_0}{\lambda t}$$

$$\frac{m N_A \sigma F}{M} = \frac{A_0}{\lambda t} \quad , \quad t_{1/2} = \frac{\ln(2)}{\lambda} \longrightarrow \lambda = \frac{\ln(2)}{t_{1/2}}$$

$$F = \frac{A_0 M}{\lambda t m N_A \sigma} = \frac{10^8 \cdot 114.82}{\frac{\ln(2)}{3240} \cdot 10 \cdot 10 \cdot 6.023 \times 10^{23} \cdot 198 \times 10^{-28}}$$

$$\boxed{F = 4.5 \times 10^{13} \ \frac{\text{neutrons}}{m^2 s}}$$