AP Chemistry

Nuclear Chemistry Questions

#1 a) $^{54}_{26}Fe + {}^{4}_{2}He \longrightarrow {}^{1}_{2,1}H + {}^{56}_{26}Fe$

b) $^{27}_{13}Al + {}^{4}_{2}He \longrightarrow {}^{30}_{15}P + {}^{1}_{0}n$

c) $^{32}_{16}S + {}^{1}_{0}n \longrightarrow {}^{1}_{1}H + {}^{32}_{15}P$

d) $^{96}_{42}Mo + {}^{2}_{1}H \longrightarrow {}^{0}_{1}n + {}^{98}_{42}Mo$ (↖ deuterium)

e) $^{98}_{42}Mo + {}^{0}_{1}n \longrightarrow {}^{99}_{43}Tc + {}^{-1}_{0}\beta$

f) $^{13}_{6}C + {}^{+1}_{0}\beta \longrightarrow {}^{14}_{6}C$

g) $^{40}_{18}Ar + {}^{4}_{2}He \longrightarrow {}^{43}_{19}K + {}^{1}_{1}H$

#2 $^{235}_{92}U \xrightarrow{\alpha} {}^{231}_{90}Th$ (Thorium) $\xrightarrow{\beta} {}^{231}_{91}Pa$ (protactinium) $\xrightarrow{\alpha} {}^{227}_{89}Ac$ (actinium) $\xrightarrow{\beta} {}^{227}_{90}Th$ (Thorium) $\xrightarrow{\alpha} {}^{223}_{88}Ra$ (radium)

$\xrightarrow{\alpha} {}^{219}_{86}Rn$ (radon) $\xrightarrow{\alpha} {}^{215}_{84}Po$ (polonium) $\xrightarrow{\alpha} {}^{211}_{82}Pb$ (lead) $\xrightarrow{\beta} {}^{211}_{83}Bi$ (bismath) $\xrightarrow{\beta} {}^{211}_{84}Po$ (polonium)

$\xrightarrow{\alpha} {}^{207}_{82}Pb$

If in doubt look at the weighted average on the periodic table, this is generally closest to most stable

#3 a. C-12 6p, 6n even, even (≠1:1) b. C-14 p/n ratio = 1:1 (takes precedence over "even") c. Si-28 14p, 14n (even/even) ≠ 1:1 ratio

#4. $t_{\frac{1}{2}} = .693/k$ $\quad k = .693/5.3\,yrs = .13$

$N = N_0 e^{-kt}$ $\quad N = (10.0\,mg)\,e^{-(.13)(21.2)} = .635 = \underline{.64\,mg}$

$N = (10.0\,mg)\,e^{-(.13)(100\,yrs)} = 2.26 \times 10^{-5} = \underline{2.3 \times 10^{-5}\,mg}$

#5. $\ln\left(\frac{R_0}{R}\right) = kt$ $\quad \ln\left(\frac{6400}{1600}\right) = k\,(6.00\,hr)$ $\quad k = .23\,hr^{-1}$

$t_{\frac{1}{2}} = .693/k = .693/.23\,hr^{-1} = 3.01 \approx \underline{3\,hr}$

Alternatively you could solve this:

1600 dps is $\frac{1}{4}$ the initial 6400 dps. $\frac{1}{4}$ dps means 2 half-lives

$(\frac{1}{2})^2 = \frac{1}{4}$. 6.00 hr = 2 half-lives $\quad t_{\frac{1}{2}} = 3\,hrs$

#6. $k = .693/t_{\frac{1}{2}} = \frac{.693}{29\,yr} = .024\,yr^{-1}$

$\ln\left(\frac{R_0}{R}\right) = kt \qquad \ln\left(\frac{80}{2.5}\right) = (.024\,yr^{-1})(t) \qquad t = 144.4 \approx \underline{144\,years}$

$\frac{144\,yrs}{29\,yrs} = 4.97 \approx \underline{5\,half\text{-}lives}$

$1985 + 144\,yrs =$ The year $\underline{2129}$

#7 Since C-12 is a stable isotope and remains constant, a C-14 to C-12 ratio of only .72 means C-14 has decayed by 28%

$\frac{1}{1}$ (original) $\longrightarrow \frac{.72}{1}$ (now) $\qquad t_{\frac{1}{2}} = \frac{.693}{k} \qquad k = \frac{.693}{5.73\times10^{3}\,yrs} = 1.21\times10^{-4}\,yr^{-1}$

$\ln\left(\frac{N_0}{N}\right) = kt \qquad \ln\left(\frac{1}{.72}\right) = 1.21\times10^{-4}\,t \qquad .329 = 1.21\times10^{-4}\,t \qquad t = \underline{2715\,yrs}$

#8 $^{239}_{94}Pu + {}^{4}_{2}He \longrightarrow {}^{240}_{95}Am + {}^{1}_{1}p + 2\,{}^{1}_{0}n$

#9 5% of original activity $(.05) = \left(\frac{1}{2}\right)^{x} \qquad \frac{\ln .05}{\ln .5} = x \qquad x = 4.32$ half-lives

days $= (8.05\,days)(4.32\,half\text{-}lives) = \underline{34.8\,days}$

#10 a) $\Delta mass = (^{60}C + {}^{1}H) - (^{59}Co + {}^{2}H) = (59.9529 + 1.00783) - (58.9332 + 2.01410) = .01343\,g$

$E = \left(1.343\times10^{-5}\frac{kg}{mol}\right)\left(3.00\times10^{8}\,m/s\right)^2 = 1.2\times10^{12}\,J/mol = \underline{1.2\times10^{9}\,kJ/mol}$ energy absorbed

b) $(^{226}Ra + {}^{4}He) - {}^{230}Th = (226.02544 + 4.00260) - 230.0332 = -.00516\,g/mol = -5.16\times10^{-6}\,kg/mol$

$E = (-5.16\times10^{-6}\,kg/mol)(3.00\times10^{8}\,m/s)^2 = -4.64\times10^{11}\,J/mol = \underline{-4.64\times10^{8}\,kJ/mol}$ energy released