Physics 225b Practice Test 2 (Show your work!) Due Mar. 24, 2003

1) For each of the following decays, list the possible mechanism for the decay, any other products you need to make the decay, and if it can be done in more than one way, which way is more likely and why.(5 pts each)

$\to {}^{218}_{85}At + \beta^- + \bar{\nu}_e \to {}^{214}_{83}Bi + \alpha$

- ${}^{218}_{84}Po \to {}^{214}_{83}Bi$

  $\xrightarrow[\alpha]{} {}^{218}_{82}Pb \xrightarrow[\beta]{+\alpha} {}^{218}_{83}Bi + \beta^- + \bar{\nu}_e$

- ${}^{214}_{83}Bi \to {}^{214}_{84}Po$

  $\to {}^{214}_{84}Po + \beta^- + \bar{\nu}_e$

- ${}^{7}_{4}Be \to {}^{7}_{3}Li$ electron capture, positron emission not energetically possible

  $+e^- \to {}^{7}_{3}Li + \nu_e$

- ${}^{12}_{7}N \to {}^{12}_{6}C$ positron emission

  $+ \beta^+ + \nu_e$ (& to a lesser extent electron capture)

Useful Masses of Particles and Isotopes

Quantity	Mass (u)	Quantity	Mass (u)
proton	1.007276	electron	5.486×10^{-4}
neutron	1.008665	${}^{1}_{1}H$	1.007825
${}^{7}_{3}Li$	7.016004	${}^{218}_{85}At$	218.008685
${}^{7}_{4}Be$	7.016929	${}^{218}_{84}Po$	218.008965
${}^{12}_{6}C$	12.000000	${}^{214}_{82}Pb$	213.999798
${}^{12}_{7}N$	12.018613	${}^{214}_{83}Bi$	213.998692
${}^{12}_{5}B$	12.014352	${}^{214}_{84}Po$	213.995177
${}^{40}_{19}K$	39.963999	${}^{40}_{20}Ca$	39.962591
${}^{40}_{18}Ar$	39.962383	${}^{2}_{1}H$	2.014102

$1u = 931.494\ MeV/c^2$

2) Suppose that the accident that Johnnie described in class actually happened. We want to know how many neutrons hit a particular worker. (Remember, the thermal neutron absorbtion cross section for water is not zero. This is not good for humans exposed to low energy neutrons!) One worker was wearing a gold ring and it became activated by the neutrons emitted during the incident. Suppose that 6 hours after the initial pulse (i.e. the burst of neutrons occured in a time much less that the half life of the activated gold) of neutrons we measure an activity of 100 decays/s in a 10g sample of gold. Estimate how many neutrons hit the worker during the pulse(20 pts). The thermal neutron cross section for ^{197}Au is 99b and the half life of ^{198}Au is 2.7 days. Show your work and state your assumptions. About how much energy did this worker absorb due to the reaction $^1_1H + ^1_0n \rightarrow ^2_1H$ if the neutron absorbtion cross section for hydrogen is (1/3)b(10 pts). You will have to make up a few numbers in this problem to get an estimate. (You will find equations 13.1 through 13.7 useful for this problem)

right after the pulse

time overwhich pulse occured

$$\lambda N(\Delta t) = R\left(1-e^{-\lambda \Delta t}\right)$$

$$\sim R\lambda\Delta t = \left(\phi\sigma \frac{m}{M} N_A\right)\lambda\Delta t$$

& we identify $\phi\Delta t$ as the number of $\frac{\text{neutrons}}{\text{Are}}$ during the pulse

and the activity we measure

$$\lambda N_{now} = \underbrace{\lambda N(\Delta t)}_{(\phi\Delta t)\sigma\frac{m}{M}N_A\lambda} \underbrace{2^{-(.25/2.7)}}_{0.9378}$$

$$\#\text{ neutrons hitting worker} \sim (1m^2)(\phi\Delta t) = 1m^2 \frac{\lambda N_{now}}{\sigma\frac{m}{M}N_A\lambda}$$

$$= (100/s)(1m^2) \Big/ (99\times10^{-28}m^2)\left(\frac{10g}{197g}\right)(6.02\times10^{23})\left(\frac{\ln(2)}{2.7d\times 86400s/d}\right)$$

$$= 7.71\times10^{10}\text{ neutrons}$$

Assuming a human is 100kg and modelled by 1x1m rectangle. water has a density of 1g/cm³ or 1Kg/(10cm)³ or 1000kg/m³ so our human "slab" is 0.1m thick & the number of hydrogen atoms in our slab is $\left(\frac{100{,}000g}{18g/mole}\cdot\frac{6.02\times10^{23}}{mole}\cdot 2\text{ Hatoms}\right) = 6.69\times10^{27}$

$$N\sigma\frac{\#\text{ thathit}}{A} = \#\text{ neutrons that got absorbed} = (6.9\times10^{27})\left(\tfrac{1}{3}\times10^{-28}m^2\right)(7.71\times10^{10}/m^2) = 1.77\times10^{10}$$

every time we make ^2_1H, we get $m(^1_0n)+m(^1_1H)-m(^2_1H)$ of energy, or

$$1.77\times10^{10}\times(1.008665u + 1.007825u - 2.014102u)\frac{931.5MeV}{u} = 3.9\times10^{10}MeV \text{ or } \sim \frac{62\mu J}{Kg} \sim \frac{1}{10}R$$

(about 300 Rads is fatal)

3)Salt substitute is a mixture of NaCl and KCl. Naturally occuring Potassium has a radioactive isotope ${}^{40}_{19}K$ which comprises 0.012 percent of naturally occuring Potassium. The half-life of ${}^{40}K$ is 1.3×10^9 years. In a 311g container of this stuff, there are 222 servings. Each serving has 290mg of sodium and 340 mg of potassium. What is the activity of this container of salt substitute(15 pts), how long ago was the natural abundance of ${}^{40}K$ the same as ${}^{39}K$ (currently 93.26 percent of naturally occuring potassium)(10 pts), and finally, what is the likely decay mechanism of ${}^{40}K$ (is reasonable to you to sell this product in the Krogers yes? discuss)(5 pts).

$$\text{activity} = \lambda N = \frac{\ln(2) \times 0.00012}{1.3\times10^9 y \cdot 3.15\times10^7 s/y} \cdot \left(\frac{.340g}{40g}\right) 6.02\times10^{23}$$

$$= 1.04\times10^4/s$$

$$0.012 = 93.26 e^{-\lambda t}$$

$$t = -\frac{1}{\lambda} \ln\left(\frac{0.012}{93.26}\right)$$

$$= 16.8 \text{ billion years ago}$$

probably β decay

$${}^{40}_{19}K \Rightarrow {}^{40}_{20}Ca$$

even even nuclei

$$\Delta E \text{ is } (39.963999u - 39.962591u)\frac{931.5MeV}{u}$$

$$= 1.31\,MeV$$

What about positron emission? ${}^{40}_{19}K \rightarrow {}^{40}_{18}Ar$

$$\Delta E \text{ is } (39.963999u - 39.962383u - 2(5.486\times10^{-4}u)) \times 931.5Me$$

0.48 MeV so this is possible!

(& electron capture too, very interesting!)

Has to be safe, we have potassium in us, so we can't get more screwed up. In any case, probably the health benefits to sodium intolerant people outweigh any small risk.