Assignment #2 solutions
Physics 274

1. The age of the leather can be determined seeing how many half-lives have passed since it was made. Since the current activity rate (0.012 Bq) is less than 0.015 Bq, we know that at least one half-life has passed. So, the leather must be older than 5730 years. Two half-lives haven't passed, though, since that would mean the activity rate would be about 0.008 Bq. The age must then be between one and two half-lives, and is much closer to one (5730 years) than two (11,460 years). So, we could say the age is probably around $\boxed{\text{7500 years (a good guess).}}$

   The other way to do this is to find A_t directly using logarithms (if you don't know what those are, though, don't worry!). The actual answer is $\boxed{\text{7636 years}}$. Our guess isn't that far off!

2. The energy released in the β decay will come from the mass difference between the parent and daughter nuclei. Since the total number of nucleons and electrons is the same on the left and right side of the decay (only one neutron has turned into a proton), the mass difference formula for beta decay (from the lecture side) is:

$$\Delta m = m_{\text{Parent}} - m_{\text{Daughter}}$$

   for the atomic masses of each isotope (measured in atomic mass units). So, if $m_{\text{Parent}} = 136.9071$ u and $m_{\text{Daughter}} = 136.9058$ u, we'll have

$$\text{Mass difference} = 136.9071 - 136.9058 = 0.0013 \text{ u}$$

   Converting this to MeV we get $\boxed{E = (931.5)(0.0013) = 1.2110 \text{ MeV}}$

3.
$$n + {}^{239}_{94}\text{Pu} \longrightarrow {}^{90}_{38}\text{Sr} + {}^{146}_{56}\text{Ba} + 4n$$

   We can find the energy release by finding the difference between the total mass before the fission (one neutron and one Pu-239 nucleus), and the total mass after (four neutrons, Ba-146 and Sr-90).

   Mass before

$$m_n + m_{Pu239} = 1.0087 + 239.0522 = 240.0609 \ u$$

   Mass after

$$4 \times m_n + m_{Ba146} + m_{Sr90} = 4 \times (1.0087) + 145.9301 + 89.9077 = 239.8726 \ u$$

The mass difference is

$$\text{Mass before} - \text{Mass after} = 240.0609 - 239.8726 = 0.1883\ u$$

So, the energy released in one fission event is:

$\boxed{\text{Released energy} = 931.5 \times 0.1883 = 175.4015 \text{ MeV}}$

(b) The molar mass of Pu-239 is about 239 g, which means that 239 g of Pu-239 will contain about 6×10^{23} atoms. So, 1 kg (1000 g) of Pu-239 will contain $(6 \times 10^{23}) \times \frac{1000}{239} = 2.5 \times 10^{24}$ atoms. If each one of those fissions, the total energy released will be $(2.5 \times 10^{24})(175.4015) = 4.4 \times 10^{26}$ MeV. Since 1 MeV$= 1.6 \times 10^{-13}$ J, then the energy released in Joules is

$\boxed{\Delta E = (2.5 \times 10^{26})(1.6 \times 10^{-13}) = 4.0 \times 10^{13} \text{ J.}}$

This is 100 times as much energy as the average annual per capita electricity consumption in LA county!!