Physics 10262 - Chapter 3 – Homework

1. Which process is used in reactors for producing neutrons? Name one nuclear reaction for neutron production that can be used in accelerators.

   (10 pts)

2. Minium was one of the main red paint pigments available to medieval and renaissance painters.
   a. How and why does it show in X-ray radiographs?
   b. Does it show in neutron activation?
   c. What possibilities does XRF or PIXE offer for analyzing the amount of minium in a painting?

   (10pts)

3. You do a PIXE analysis and a complementary neutron activation analysis of the red coat worn by St. Christopherus in the painting “Die vierzehn Nothelfer” by Lucas Cranach.
   a. The PIXE spectrum indicates a mix of vermillion and lead-white in the color of the red coat, what would you see with neutron activation?
   b. What would a radiograph of the red coat show?

   (15pts)
4. You radiate a small section of Marc Chagall’s “American Windows” in the Chicago Art Institute containing Cobalt blue (CoAl₂O₄) with a flux of $10^{10}$ neutrons for 60 minutes. The cross section for neutron capture on $^{59}$Co is 0.1 barn, the glass sheet contains a 0.1mm thick layer of blue and an estimated area of 1000 cm$^2$. The neutron activation produces radioactive $^{60}$Co with a half live of 5.27 years. Calculate how much $^{60}$Co you produce and determine the overall activity 8 days and 80 days after the activation process. 

5. Consider the Rembrandt’s self-portrait. The dominating pigment is umber with a 1% contribution of bone black for the under drawing. Neutron activation produces radioactive $^{56}$Mn ($T_{1/2}=2.58$ h) from the umber and $^{32}$P ($T_{1/2}=14.26$ d) from the bone black. Assuming identical cross section for the associated neutron capture reactions calculate

a. the ratio of the production of $^{56}$Mn and $^{32}$P over the activation period of 10 h.

b. the relative activity $A(^{56}\text{Mn})/A(^{32}\text{P})$ after a 1d, 2d, 5d, 8d, and 20d period following the activation.
6. You want to determine the isotope ratio of $^{16}\text{O}$ and $^{18}\text{O}$ as well as $^{12}\text{C}$ and $^{13}\text{C}$ in a section of the Elgin Marbles, which were part of the Parthenon frieze removed by the British Lord Elgin in 1801-1805. The isotope analysis will help to identify its provenance of the material. You use an isotope separator magnet with a magnetic field of 1 Tesla. Calculate the radii of the trajectory of $^{13}\text{C}$, $^{16}\text{O}$, and $^{18}\text{O}$ if the radius for $^{12}\text{C}$ is $R=1\text{ m}$. (10pts)

7. Using a mass separator you measure the carbon isotope ratio $^{13}\text{C}/^{12}\text{C}$ to be 0.011203 of Kennewick Man, a more than 9000 year old skeleton found at the Washington shore of the Columbia River.
   a. Derive $\delta^{13}\text{C}$ of the material considering that the PDB belemnite standard has an isotope ratio of $^{13}\text{C}/^{12}\text{C}=0.0112372$.
   b. Based on this value, what would you consider was his favorite diet?
   c. The worldwide average value for $\delta^{13}\text{C}$ is -23.23, what is the average isotope ratio $^{13}\text{C}/^{12}\text{C}$? (15pts)