PHYS 202 OUTLINE FOR PART VI

NUCLEAR PHYSICS

X-RAYS AND ATOMIC STRUCTURE

A. Energy and wavelengths S-66

1. $E_{photon} = hf$; $f\lambda = c$; therefore, $E = hc/\lambda$
2. $E_{edge} \approx 13.6\,\text{eV}\,(Z-1)^2$

B. Interference (x-ray diffraction)

1. $n_{max}\,\lambda = 2\,d\,\sin(\theta_{max})$

C. Absorption S-67

1. intensity (I) vs distance (x) and material (μ):

$$I(x) = I_o e^{-\mu x}$$

2. intensity vs wavelength or Energy: $\mu(\lambda)$ or $\mu(E)$
   - (a) photoelectric effect: $\mu\downarrow$ ($I\uparrow$) as $E_\gamma\uparrow$ ($\lambda_\gamma\downarrow$)
   - (b) Compton scattering: $\mu\downarrow$ ($I\uparrow$) as $E_\gamma\uparrow$ ($\lambda_\gamma\downarrow$)
   - (c) pair production: $\mu\uparrow$ ($I\downarrow$) as $E_\gamma\uparrow$ ($\lambda_\gamma\downarrow$)

<u>Supplementary Problems (S-):</u>

66. Explain how an x-ray machine produces x-rays. This should include a discussion of discrete and continuous spectra.

67. What are the three main means of absorbing x-rays and for which energy range is each dominant?

<u>Answers to Supplementary Problems:</u>

66. A beam of electrons is accelerated and then smashed against a target. The electrons lose energy in the collision which shows up as the continuous spectrum of x-rays (photons of different size depending on the energy lost by the electrons in the collision); and the electrons knock electrons out of the target atoms which then re-absorb electrons and then emit discrete x-rays based on the energy levels of the target atoms.

67. (a) photoelectric effect, dominant below 1 Mev; (b) Compton scattering, dominant between 1 Mev and 5 Mev; (c) pair production, dominant above 5 Mev.

NUCLEAR PHYSICS

A. Nuclear structure

1. atomic number
2. atomic mass
3. nuclear binding: nuclear force and nuclear energy

B. Radioactivity S-68 to 71

1. types
   - (a) photons (gamma rays, γ): can't change q or m, accompanies other reactions
   - (b) electrons (beta-, β^-) and positrons (beta+ ,β^+): changes q but not m
   - (c) alpha (α) particles: changes both q and m
   - (d) induced radioactivity (ex. production of radioactive C^{14} in the atmosphere)
2. half-life: $N \propto \Delta N/\Delta t$ leads to $N = N_o e^{-\lambda t}$

   so when $N = ½N_o$ then $t = T_{½}$ and $e^{-\lambda T} = ½$, or $T_{½} = \ln(2)/\lambda$
3. activity: $A = \lambda N$ so $A(t) = A_o e^{-\lambda t}$
4. absorption of each

C. Nuclear Power S-72 to 74

1. fission
   - (a) the bomb
   - (b) the reactor
     - (1) power and fuel
     - (2) decay products
     - (3) breeder reactors
     - (4) relative safety
2. fusion
   - (a) the bomb
   - (b) controlled fusion
     - (1) magnetic confinement
     - (2) inertial confinement

D. Biological effects S-75,76

1. units
2. background levels
3. recommended maximum levels

E. Sub-atomic particles - quarks!

Supplementary Problems:

68. Th^{234} decays by beta decay. What does it decay to? Write the "equation" for this reaction.

69. The stable isotopes of iron are ${}_{26}Fe^{56}$, ${}_{26}Fe^{57}$, and ${}_{26}Fe^{58}$. a) What type of decay would ${}_{26}Fe^{61}$ most likely undergo? b) What would it become? c) What type of decay would ${}_{26}Fe^{52}$ most likely undergo? d) Write the "equation" for this reaction. e) Would Fe^{61} or Fe^{52} also be likely to decay by electron capture?

70. a) What type of decay would C^{14} most likely undergo? b) What would the "equation" for this reaction be? c) What would the energy released in this decay be? (The mass of C^{14} is 14.003233 amu.)

71. The half life of C^{14} is 5730 years. a) What is the decay constant for C^{14}? b) The ratio of C^{14} to C^{12} in the atmosphere is 1.3×10^{-12}. What is the present activity of a 12 gram sample of carbon taken from a "modern" bone? c) A 12 gram sample of carbon taken from a bone at an archeo- logical site has an activity of 35 counts per minute. Assuming that C^{14} was formed at the same rate then as it is now, how old is the bone?

72. a) What is a moderator in a nuclear reactor? b) What is it used? c) Explain why it is impossible for a nuclear reactor to blow up as a nuclear bomb.

73. What is a breeder reactor?

74. Distinguish fusion from fission. Which do present reactors employ? Which do present nuclear weapons employ?

75. Distinguish between exposure dose, absorption dose, and activity; and know which units go with which doses.

76. Know what the approximate background level of radiation is, and know what the whole-body dose limits are for the general population.

ANSWERS TO SUPPLEMENTARY PROBLEMS:

68. ${}_{91}Pa^{234}$; ${}_{90}Th^{234} \rightarrow {}_{91}Pa^{234} + {}_{-1}\beta^{0}$ + antineutrino + gamma.

69. a) β; b) ${}_{27}Co^{61}$; c) positron (β^{+}); d) ${}_{26}Fe^{52} \rightarrow {}_{25}Mn^{52} + {}_{+1}\beta^{0}$ + neutrino; e) ${}_{26}Fe^{52}$.

70. a) β; b) ${}_{6}C^{14} \rightarrow {}_{7}N^{14} + {}_{-1}\beta^{0}$ + antinuetrino; c) 0.148 MeV.

71. a) 1.21×10^{-4} /yr = 2.30×10^{-10} /min; b) 179.4 counts/min; c) 13,510 yrs.