PHYS 202 OUTLINE FOR PART VI

NUCLEAR PHYSICS

X-RAYS AND ATOMIC STRUCTURE

A. Energy and wavelengths

1. $E_{\text{photon}} = hf; \quad f \lambda = c; \quad$ therefore, $E = hc/\lambda$

2. $E_{\text{edge}} \approx 13.6 \text{ eV} \ (Z-1)^2$

B. Interference (x-ray diffraction)

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

C. Absorption

1. intensity (I) vs distance (x) and material ($\mu$):
   
   $I(x) = I_0 e^{-\mu x}$

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 $E_\gamma \uparrow (\lambda_\gamma \downarrow)$

Supplementary Problems (S-):

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?

Answers to Supplementary Problems:

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

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: \( N \propto \frac{\Delta N}{\Delta t} \) leads to \( N = N_0 e^{-\lambda t} \)
   so when \( N = \frac{1}{2}N_0 \) then \( t = T_{\frac{1}{2}} \) and \( e^{\lambda T} = \frac{1}{2} \), or \( T_{\frac{1}{2}} = \ln(2)/\lambda \)

3. activity: \( A = \lambda N \) so \( A(t) = A_0 e^{-\lambda t} \)
4. absorption of each

C. Nuclear Power

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

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 \(26\text{Fe}^{56}\), \(26\text{Fe}^{57}\), and \(26\text{Fe}^{58}\). a) What type of decay would \(26\text{Fe}^{61}\) most likely undergo? b) What would it become? c) What type of decay would \(26\text{Fe}^{52}\) most likely undergo? d) Write the "equation" for this reaction. e) Would \(26\text{Fe}^{61}\) or \(26\text{Fe}^{52}\) 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 1.3x10\(^{-12}\). 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 archeological 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}\text{Pa}^{234}; \quad ^{90}\text{Th}^{234} \rightarrow ^{91}\text{Pa}^{234} + \beta^0 + \text{antineutrino} + \text{gamma}\.

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

70. a) \(\beta\); b) \(^{6}\text{C}^{14} \rightarrow ^{7}\text{N}^{14} + \beta^0 + \text{antineutrino}\); c) 0.148 MeV.

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