12.2 NUCLEAR PHYSICS	*HW/Study Packet*

HL	
Required: READ Tsokos (6^{th} Ed), pp 505-515	Supplemental: Cutnell and Johnson, pp 652-652, 970-973

REMEMBER TO….

- ✓ *Work through all of the 'example problems' in the texts as you are reading them*
- ✓ *Refer to the **IB Physics Guide** for details on what you need to know about this topic*
- ✓ *Refer to the **Study Guides** for suggested exercises to do each night*
- ✓ *First try to do these problems using only what is provided to you from the **IB Data Booklet***
- ✓ *Refer to the solutions/key ONLY after you have attempted the problems to the best of your ability*

UNIT OUTLINE

I. DETERMINING NUCLEAR SIZES

A. DETERMINING RADII
B. DETERMINING MASSES
C. DETERMINING NUCLEAR ENERGY LEVELS

II. RADIOACTIVE DECAY

A. BETA DECAY AND NEUTRINOS
B. THE RADIOACTIVE DECAY LAW

FROM THE IB DATA BOOKLET

$$R = R_0 A^{1/3} \qquad A = \lambda N_0 e^{-\lambda t}$$

$$N = N_0 e^{-\lambda t} \qquad \sin\theta \approx \frac{\lambda}{D}$$

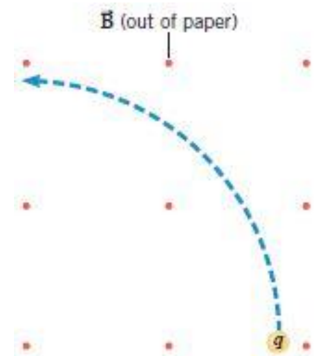
WHAT YOU SHOULD BE ABLE TO DO AT THE END OF THIS TOPIC

- □ Solve problems of closest approach and understand how nuclei have well-defined radii
- □ Describe a scattering experiment including location of minimum intensity for diffracted particles based on their de Broglie wavelength
- □ Explain deviations from Rutherford scattering in high energy experiments
- □ Explain how radii of nuclei may be estimated from charged particle scattering experiments
- □ Describe a mass spectrometer, how it can be used to determine masses of nuclei, and its implications for isotope existence
- □ Describe evidence for the existence of nuclear energy levels
- □ Discuss β^+ decay and the theoretical arguments that have been used to postulate the existence of the neutrino
- □ Use the radioactive decay laws in solving problems
- □ Derive the relationship between half-life and decay constant and be able to use them in solving problems
- □ Understand that the decay constant is a probability of decay per unit time
- □ Describe methods of obtaining short and long half-lives from experimental data

HOMEWORK PROBLEMS:

1. An experiment is carried out in which alpha (α) particles of initial kinetic energy 5.0 MeV are fired at a piece of gold foil. The proton number of gold is 79. Determine the distance of closest approach of an alpha (α) particle to a gold nucleus. **[4.5×10^{-14} m]**

2. A charged particle enters a uniform magnetic field and follows the circular path shown.



a) Is the particle positively or negatively charged? Why?

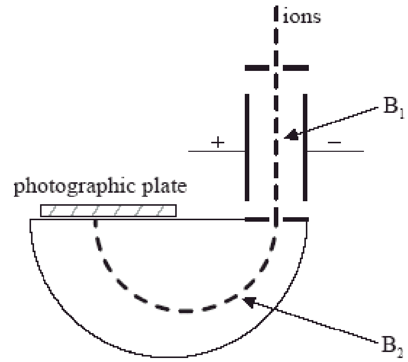
b) The particle's speed is 140 m/s, the magnitude of the magnetic field is 0.48 T, and the radius of the path is 960 m. Determine the mass of the particle, given that its charge has a magnitude of 8.2×10^{-4} C. **[2.7×10^{-3} kg]**

3. The solar wind is a thin, hot gas given off by the sun. Charged particles in this gas enter the magnetic field of the earth and can experience a magnetic force. Suppose that a charged particle traveling with a speed of 9.0×10^{6} m/s encounters the earth's magnetic field at an altitude where the field has a magnitude of 1.2×10^{-7} T. Assuming that the particle's velocity is perpendicular to the magnetic field, find the radius of the circular path on which the particle would move if it were

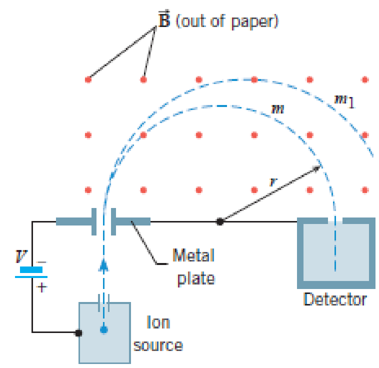
a) an electron **[4.3×10^{2} m]**

b) a proton **[7.8×10^{5} m]**

4. The diagram is a schematic representation of the Bainbridge mass spectrometer. Positive ions are injected between the plates of the speed selector. Describe the direction of the magnetic fields B_1 and B_2 and explain your answers fully. **[both fields out of the page]**



5. When beryllium-7 ions pass through a mass spectrometer, a uniform magnetic field of 0.283 T curves their path directly to the center of the detector as shown. For the same accelerating potential difference, what magnetic field should be used to send beryllium-10 ions to the same location in the detector? Both types of ions are singly ionized. **[0.338 T]**



6. Two isotopes of carbon, carbon-12 and carbon-13, have masses of 19.93×10^{-27} kg and 21.59×10^{-27} kg, respectively. These two isotopes are singly ionized (+*e*) and each is given a speed of 6.667×10^5 m/s. The ions then enter the bending region of a mass spectrometer where the magnetic field is 0.8500 T. Determine the spatial separation between the two isotopes after they have traveled through a half-circle. **[1.63×10^{-2} m]**

7. The activity of a freshly prepared sample of bismuth-212 is 2.80×10^{13} Bq. After 80.0 minutes the activity is 1.13×10^{13} Bq. Determine the half-life of bismuth-212. **[61.1 min]**

8. A radioactive emitter I - 132 has a half-life of 2.3 hours. Calculate the mass needed initially to produce an activity of 6 kBq. **[1.58×10^{-14} g]**

9. Initially the number of atoms in a radioactive element X is 2.000×10^{21}. Its half-life is 4 hours.

a) Calculate the number of atoms which have disintegrated in 6 hours. **[1.292×10^{21}]**

If the energy liberated per decay is 3.0×10^{-13} J, find

b) the total energy liberated. **[390×10^{6}J]**

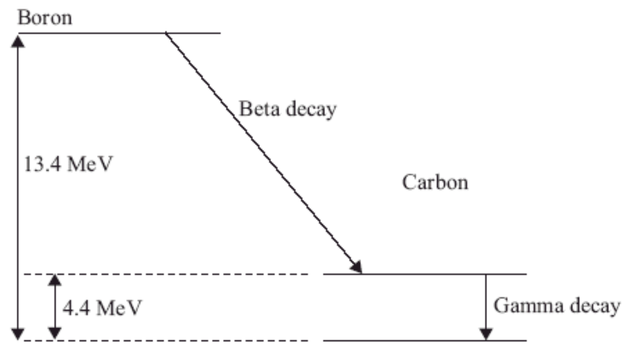
c) the average power developed. **[18×10^{3} W]**

10. Radium-222 disintegrates initially at a rate of 5.00 kBq. If the decay constant is 2.00×10^{-6} s^{-1},

a) determine the half-life. **[4 days]**

b) calculate the initial mass of the element. **[9.25×10^{-13} g]**

11. The diagram shows some of the nuclear energy levels of the boron isotope ${}^{12}_{5}\mathrm{B}$ and the carbon isotope ${}^{12}_{6}\mathrm{C}$. Differences in energy between the levels are indicated on the diagram. A particular beta decay of boron and a gamma decay of carbon are marked on the diagram.



a) Calculate the wavelength of the photon emitted in the gamma decay. **[2.8 × 10^{-13} m]**

b) Calculate the maximum kinetic energy of the electron emitted in the beta decay indicated. **[9.0 MeV]**

c) Explain why the electrons emitted in the indicated beta decay of boron do not always have the kinetic energy calculated in (b).