7.2 RADIOACTIVE DECAY *HW/Study Packet*

SL/HL	
Required: Tsokos, pp 373-378 Hamper pp 244-255	Supplemental: Cutnell and Johnson, pp 963-979, 986-990

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. RADIOACTIVITY
- A. RADIOACTIVE DECAY – WHAT HAPPENS?
- B. BIOLOGICAL EFFECTS OF IONIZING RADIATION

II. TIMESCALES OF RADIOACTIVE DECAY
- A. HALF-LIFE
- B. DECAY CURVES

FROM THE IB DATA BOOKLET

Nothing explicitly useful for this topic.

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

- □ Describe the phenomenon of radioactive decay - alpha, beta, and gamma radiations.
- □ Describe the biological effects of ionizing radiation – direct and indirect effects.
- □ Explain what makes some nuclei stable and others unstable in terms of relative numbers of protons, neutrons and forces involved.
- □ Define half-life and determine it from a decay curve.
- □ Recognize that the rate of decay decreases exponentially with time.

HOMEWORK PROBLEMS:

1. For each of the following write the nuclear equation for the decay

a) When ${}^{234}_{90}Th$ decays to ${}^{234}_{91}Pa$

b) When ${}^{234}_{91}Pa$ decays to ${}^{234}_{92}U$

c) When ${}^{234}_{92}U$ decays to ${}^{230}_{90}Th$

2. Write out the nuclear equation of the following given that

a) ${}^{218}_{84}Po$ decays to Pb by emitting an alpha particle

b) ${}^{211}_{83}Bi$ decays to Po by emitting a beta particle

c) ${}^{211}_{83}Bi$ decays to Tl by emitting an alpha particle

3. The radioactive isotope Po 84, emits an α-particle according to the equation below when it decays

$$^{218}_{84}\mathrm{Po} \rightarrow \alpha + {}^{x}_{y}\mathrm{Pb}.$$

What are the values of x and y?

4. What is the wavelength (in a vacuum) of the 0.186-MeV γ–ray photon emitted by radium ${}^{226}_{88}Ra$?

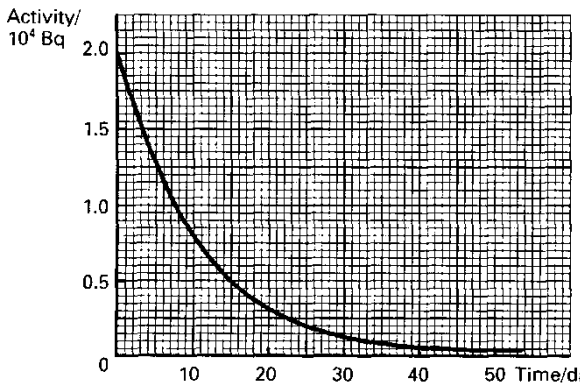
[6.68 x 10^{-12} m]

5. A sample of iodine contains atoms of the radioactive isotope iodine 131, ${}^{131}\mathrm{I}$, and atoms of the stable isotope iodine 127. Iodine has a proton number of 52 and the radioactive isotope decays into xenon 131 (${}^{131}\mathrm{Xe}$) with the emission of a single negatively charged particle.

a) State the similarities and differences in composition of the nuclei of the two isotopes of iodine.

b) What particle is emitted when iodine 131 decays? Write the nuclear equation which represents the decay.

c) The diagram shows how the activity of a freshly prepared sample of the iodine varies with time. Calculate the half-life of iodine 131



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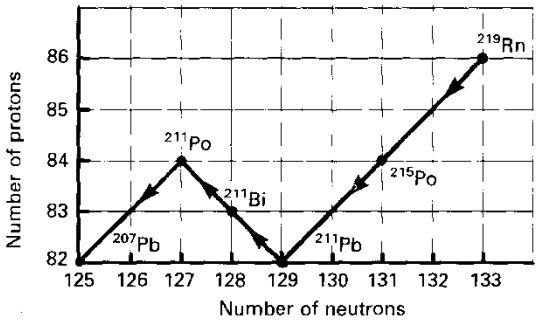
6. A decay sequence for a radioactive atom of radon-219 to a stable lead-207 atom is as shown below.



a) What do the numbers on the symbol $^{207}_{82}\mathrm{Pb}$ represent?

b) i) Write down a nuclear equation representing the decay of $^{219}_{86}\mathrm{Rn}$ to $^{215}_{84}\mathrm{Po}$

ii) Write down the name of the particle which is emitted in this decay.

c) i) What particle is emitted when $^{211}_{83}\mathrm{Bi}$ decays?

ii) What happens within the nucleus to cause this decay?

d) The half-life of $^{219}_{86}\mathrm{Rn}$ is 4.0 seconds. At a time t = 20 seconds, what fraction of the radon atoms present at time t = 0, will be 'undecayed'? **[1/64]**

7. Suppose that 3.0×10^7 radon atoms are trapped in a basement at the time the basement is sealed against any further entry of the gas. The half-life of radon is 3.83 days.

a) How many radon atoms remain after 31 days? **[1.2×10^5]**

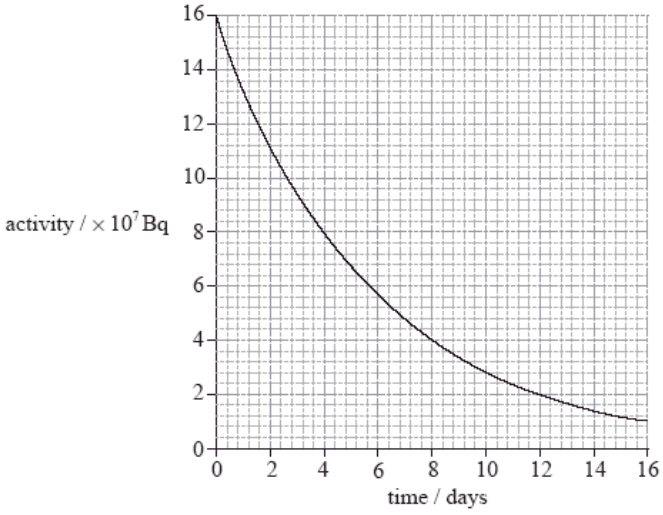
b) Find the activity at the time the basement is sealed. **[60 Bq]**

c) Find the activity after 31 days. **[0.23 Bq]**

8. Iodine-124 (I-124) is an unstable radioisotope with proton number 53. It undergoes beta plus decay to form an isotope of tellurium (Te).

a) State the reaction for the decay of the I-124 nuclide.

b) The graph shows how the activity of a sample of iodine-124 changes with time.



i) State the half-life of iodine-124. **[4 days]**

ii) Calculate the activity of the sample at 21 days. **[4.2 x 10^6 Bq]**

iii) A sample of an unknown radioisotope has a half-life twice that of iodine-124 and the same initial activity as the sample of iodine-124. On the axes, draw a graph to show how the activity of the sample would change with time. Label this graph X.

iv) A second sample of iodine-124 has half the initial activity as the original sample of iodine-124. On the axes opposite, draw a graph to show how the activity of this sample would change with time. Label this graph Y.

9. In a β^+ (positron) decay, a positron is emitted along with a neutrino, and a γ-ray photon. Although the energy spectrum for γ-rays involved is discrete, the energy spectrum for the positrons is continuous.

a) State the difference between a discrete energy spectrum and a continuous energy spectrum.

b) Explain how the existence of the neutrino accounts for the continuous nature of the positron energy spectrum.

c) Sodium-22 is a radioisotope used in nuclear medicine that undergoes β^+ decay. The half-life of sodium-22 is 2.6 years. A sample of sodium-22 has an initial activity of 6.2×10^9 Bq.

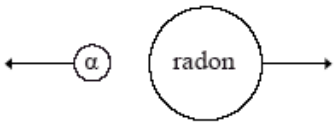
i) Calculate the decay constant of sodium-22. **[0.27 yr^{-1}]**

ii) Calculate the activity of the sample of sodium-22 after 8.0 years. **[7.2 x 10^8 Bq]**

10. A nucleus of radium-91 ($^{226}_{91}\mathrm{Ra}$) undergoes alpha particle decay to form a nucleus of radon (Rn).

a) Identify the proton number and nucleon number of the nucleus of Rn. **[89,222]**

b) Immediately after the decay of a stationary radium nucleus, the alpha particle and the radon nucleus move off in opposite directions and at different speeds as shown.



Determine the ratio $\dfrac{\text{initial kinetic energy of alpha particle}}{\text{initial kinetic energy of radon atom}}$.

[~56]

c) The initial kinetic energy of the alpha particle is 4.9 MeV. As the alpha particle passes through air, it loses all its kinetic energy by causing the ionization of 1.7×10^5 air molecules. Estimate, in joules, the average energy needed to ionize an air molecule. **[4.6 x 10^{-18} J]**

d) Explain why a beta particle has a longer range in air than an alpha particle of the same energy.