Nuclear Physics Practice Items

1. The species $^{1}_{1}\mathbf{H}$, $^{2}_{1}\mathbf{H}$, and $^{3}_{1}\mathbf{H}$ are

A. allotropes
B. homologs
C. isomers
D. isotopes

2. In 1932 J. Chadwick bombarded beryllium with α-particles and found that highly energetic, uncharged particles were emitted. This neutral radiation could in turn knock protons out of the nuclei of other substances. These particles were

A. positrons
B. neutrinos
C. beta particles
D. neutrons

3. The rest mass of a free proton is

A. greater than ½ the mass of a ^{12}C atom.
B. less than ½ the mass of a ^{12}C atom.
C. equal to the rest mass of a free neutron.
D. greater than the rest mass of a free neutron.

4. The decay rate of a radioactive sample is often referred to as its

A. half life
B. rate constant
C. activity
D. emissivity

5. Which of the following is the SI unit for the activity of a quantity of radioactive material?

A. becquerel (Bq)
B. curie (Ci)
C. sievert (Sv)
D. rutherford (Rd)

6. A particle moving through the water surrounding the core of a nuclear reactor emits Cherenkov radiation. Cherenkov radiation is emitted when a charged particle passes through a dielectric medium at a speed greater than the phase velocity of light in that medium. The index of refraction of water is 1.33. Determine the minimum speed at which the particle must be traveling through the water.

A. 0.67 *c*
B. 0.75 *c*
C. 1.00 *c*
D. 1.33 *c*

7. In α decay

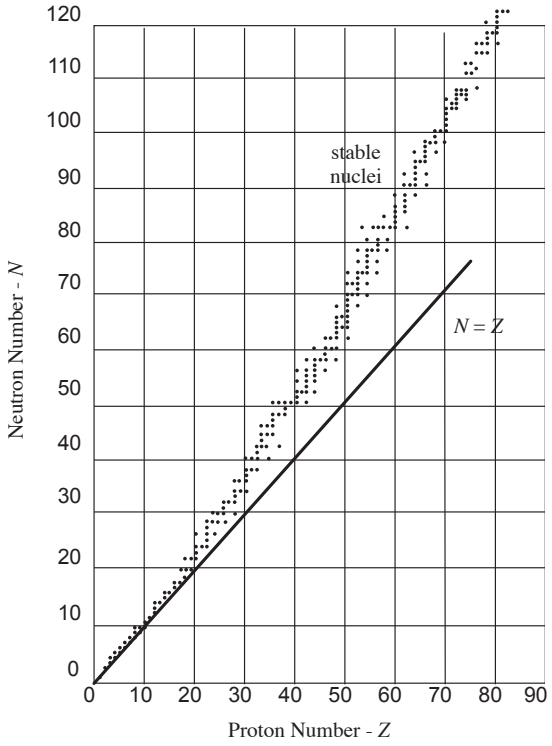
A. *Z* decreases by 1 and *A* does not change.
B. *Z* increases by 1 and *A* does not change.
C. *Z* decreases by 4 and *A* decreases by 2.
D. *Z* decreases by 2 and *A* decreases by 4.

8. Which of the following are β^- emitters with a long history of use as radiolabels within life sciences research?

A. ^{2}H, ^{14}C, ^{18}O, ^{32}P
B. ^{2}H, ^{13}C, ^{32}P, ^{35}S
C. ^{3}H, ^{14}C, ^{15}N, ^{35}S
D. ^{3}H, ^{14}C, ^{32}P, ^{35}S

9. Stable nuclides are represented by a narrow band of proton-to-neutron ratios on the graph of neutron number vs. proton number below. What type of radioactive decay would you expect to occur for the isotope of tin, $^{126}_{50}\mathbf{Sn}$?

A. β^+ decay
B. β^- decay
C. electron capture
D. α decay



10. Which of the following is the daughter nucleus produced by the β^+ decay of fluorine-18?

A. oxygen-18
B. neon-18
C. nitrogen-14
D. fluorine-17

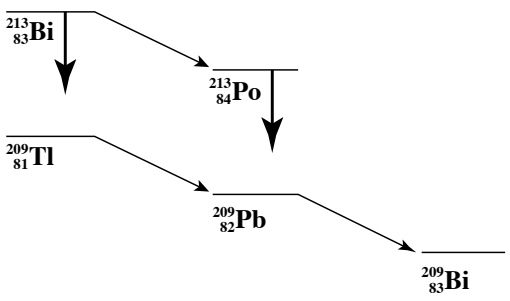
The following passage pertains to questions 11 - 15.

There can be therapeutic benefit to destruction or weakening of cells using radiation. Short-range radiotherapy is known as brachytherapy. Localization in the target organ may occur through the radionuclide being attached to a suitable biological compound. In most cases beta emitters are utilized.

An ideal therapeutic radioisotope is a strong beta emitter with just enough gamma to enable imaging. Lutetium-177 is prepared from ytterbium-176 which is irradiated to become Yb-177 (which decays rapidly to Lu-177). Similarly, yttrium-90 is used for treatment of cancer, particularly non-Hodgkin's lymphoma and liver cancer, and it is being used more widely, including for arthritis treatment. Lu-177 and Y-90 are becoming the main RNT agents.

With a short particle range and high linear energy transfer, α-emitting radionuclides demonstrate high cell-killing efficiencies. Development of therapeutic applications for α-emitting radionuclides is a major research area. For targeted alpha therapy (TAT), actinium-225 is often used, from which the daughter bismuth-213 can also be obtained (via three alpha decays) to label targeting molecules. The bismuth is obtained by elution from an Ac-225/Bi-213 generator in which the Ac-225 is firmly retained by the sorbent, and Bi-213 is eluted with various complexing agents. Bi-213 has a 46-minute half-life. The Ac-225 (half-life 10 days) is formed from radioactive decay of radium-225, the decay product of long-lived thorium-229, which is obtained from decay of uranium-233, which in turn is formed from thorium-232 by neutron capture in a nuclear reactor.

Bi-213 Decay Scheme



Ac-225 itself is an alpha-emitter and may be used directly, bonded to a protein or antibody such as anti-PSMA (anti-prostate-specific membrane antigen) for prostate cancer. Anti-Tac, a monoclonal antibody directed to the human interleukin 2 (IL-2) receptor, has been successfully conjugated to bismuth-212 (half-life 60.5 min) by use of a bifunctional ligand. The alpha decays of Bi-212 and Po-212 are the active ones destroying cancer cells over a couple of hours. Considerable medical research is being conducted worldwide into the use of radionuclides attached to highly specific biological chemicals such as immunoglobulin molecules (monoclonal antibodies). The eventual tagging of these cells with a therapeutic dose of radiation may lead to the regression of some diseases.

11. Which type of radioactive decay is involved in the conversion of $^{209}_{82}\mathbf{Pb}$ into $^{209}_{83}\mathbf{Bi}$?

A. β^+ decay
B. β^- decay
C. electron capture
D. α decay

12. Which of the following is an intermediate in the decay pathway from $^{225}_{89}\mathbf{Ac}$ to $^{213}_{83}\mathbf{Bi}$?

A. $^{209}_{81}\mathbf{Tl}$
B. $^{221}_{88}\mathbf{Ra}$
C. $^{217}_{85}\mathbf{At}$
D. $^{213}_{84}\mathbf{Po}$

13. 0.32 microCi was targeted by Bi-212-labeled anti-Tac to IL-2 receptor-positive adult T-cell leukemia line HUT-102B2. What was the residual activity of the Bi-212-labeled antibodies three hours after administration?

A. 0.02 microCi
B. 0.04 microCi
C. 0.08 microCi
D. 0.16 microCi

14. A sample of Ac-225 possessed an activity of 7.0 mCi at the time of shipment from Oak Ridge National Laboratory. Upon receipt at UCLA its activity was 2.9mCi. How much time elapsed during shipment?

A. 2 days
B. 4 days
C. 8 days
D. 12 days

15. Which of the following is a factor that the radionuclides Lu-177 and Y-90 have in common?

A. Both Lu-177 and Y-90 may decay to a daughter nucleus in an excited state.
B. Compared to α emitters, Lu-177 and Y-90 emit particles which are less penetrating.
C. They are both positron emitters producing gamma photons through pair annihilation.
D. In their decay process, a proton changes to a neutron in the nucleus.