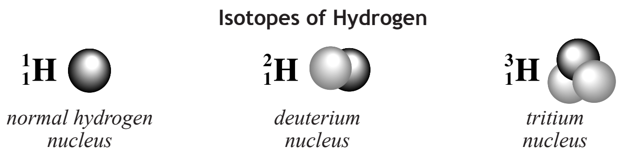
Nuclear Physics
Answers and Explanations

1. D

Isotopes are forms of the same element that contain equal numbers of protons but different numbers of neutrons in their nuclei.



2. D

Of the answer choices the only uncharged particles are neutrinos and neutrons. However, it is only through rare and special circumstances that the interactions of neutrinos with normal matter may be observed. Chadwick's experiment is credited as being the discovery of the neutron.

3. A

By definition one amu equals 1⁄12 mass of a ^{12}C atom. The rest mass of a free proton is 1.0073 amu, and the rest mass of a free neutron is 1.0086 amu. This may seem contradictory given that there are six protons and six neutrons in the ^{12}C nucleus. How can there be less mass in the ^{12}C atom than there is in twelve free protons and neutrons. The binding energy of carbon-12 is the answer. This is around 92MeV which accounts for the missing mass energy equivalent of 0.064 amu in the difference between twelve free protons and neutrons versus the ^{12}C nucleus.

4. C

The rate of decay in disintegrations per second is called the activity of a sample. The activity depends on the number of nuclei present and their tendency to undergo decay, reflected by the decay constant λ of the radioactive species. Activity is directly proportional to the amount of nuclide present.

$$A = \frac{\Delta N}{\Delta t} = -\lambda N$$

A = activity (disintegrations per second)
N = number of radioactive nuclei
t = time
λ = decay constant

5. A

The SI unit of activity is called the becquerel (Bq):

$$1\text{Bq} = 1 \text{ decay/s}$$

The curie (Ci) (or, more commonly, milli- and microcuries) is often used instead. The curie was originally calibrated as the activity of one gram of radium.

$$1\text{Ci} = 3.7 \times 10^{10} \text{ decay/s}$$

The rutherford (Rd) is defined as an activity of one million decays per second. It is therefore equivalent to one megabecquerel.

The sievert (Sv) is the SI unit of ionizing radiation dose. It is a measure of the health effect of low levels of ionizing radiation on the human body. The sievert is important in dosimetry and radiation protection. One sievert carries with it a 5.5% chance of eventually developing cancer (based on a linear no-threshold model). One sievert equals 100 rem.

6. B

As described, 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 a medium is defined as the ratio of the speed of light in a vacuum to the speed of light in the medium.

$$n = \frac{c}{v}$$

To determine the speed of light in a particular medium, divide the speed of light by the index of refraction.

$$v = \frac{c}{n}$$

$$v = \frac{c}{1.33} = \frac{c}{4/3} = \frac{3}{4}c$$

7. D

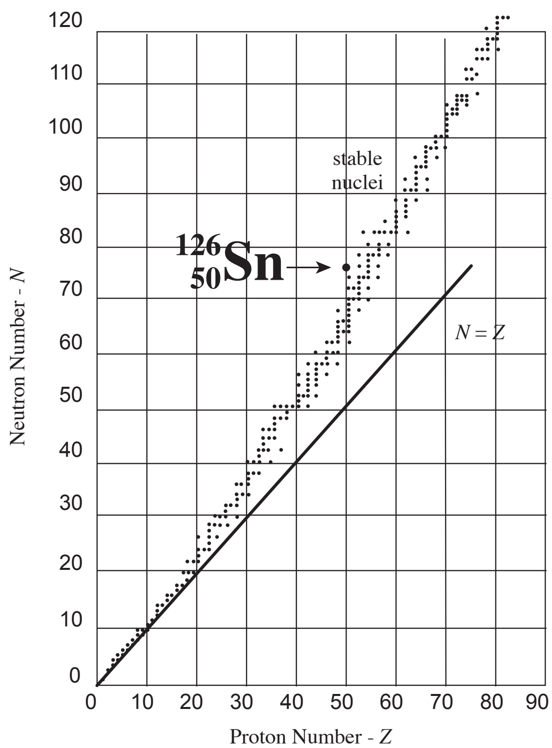
A nuclei undergoes alpha decay by emitting an α particle, which is identical to a helium nucleus – $^4_2He^{2+}$ – two protons and two neutrons. Atomic number, Z, decreases by 2 and mass number, A, decreases by 4.

8. D

^{3}H, ^{14}C, ^{32}P, and ^{35}S are β^- emitters. Although ^{2}H, ^{13}C, ^{15}N, and ^{18}O are also often utilized in life science research, those four are heavy stable isotopes, not radioactive. Unlike the β^- emitters, those isotopes are detected through their effect on the molecular weight of the substance into which they have been substituted.

9. B

The isotope of tin, $^{126}_{50}\mathbf{Sn}$, referenced in the question is not within the island of stability. It has too many neutrons. For such radionuclides, β^- emission may occur, leading to a daughter nucleus closer to or within the island of stability. Through β^- emission a neutron in the nucleus will be transformed into a proton.



10. A

In ß$^+$ decay, a ß$^+$ particle, (a positron, the anti-particle of the electron) and a neutrino, *v*, are emitted. A proton changes into a neutron in the nucleus (Z decreases by 1 with A unchanged).

$$^{18}_{9}\mathbf{F} \longrightarrow {}^{18}_{8}\mathbf{O} + {}^{0}_{1}\beta^{+} + v$$

11. B

In ß$^-$ decay, a ß$^-$ particle, which is a high speed electron, and an antineutrino, $\bar{\upsilon}$, are emitted. A neutron changes into a proton in the nucleus (Z increases by 1 with A unchanged).

$$^{209}_{82}\mathbf{Pb} \longrightarrow {}^{209}_{83}\mathbf{Bi} + {}^{0}_{-1}\beta^{-} + \bar{\upsilon}$$

12. C

As the passage describes, bismuth-213 is obtained after three alpha decays from actinium-225. A nuclei undergoes alpha decay by emitting an α particle, which is identical to a helium nucleus – $^{4}_{2}\mathbf{He}^{2+}$– two protons and two neutrons. Z decreases by 2 and A decreases by 4. The sequence of three alpha decays would begin with actinium-225 then to francium-221 then to astatine-217 and finally to bismuth-213.

13. B

Given that the half-life of B-212 is 60.5 minutes, as the passage indicates, a period of three hours is very close to three half lives. After three half lives, activity will have decreased from 0.32 microCi. to ⅛ value, or 0.04 microCi.

14. D

At the receipt of shipment the sample of actinium-225 has lost more than half of its original activity. In other words, a greater duration of time than a single half-life has passed. The half-life of actinium-225 is given in the passage as 10 days, 12 days is the amount of time which has passed.

15. A

As the passage indicates, they are both beta emitters whose decay reaction may lead to production of a gamma ray. Gamma decay occurs when a nucleus in an excited energy state, very often as the result of a prior decay event, emits a very high energy photon, a gamma ray, as it transitions to a lower energy state. For both of these isotopes, the majority of decay events land on the ground state daughter nucleus, but a percentage with each branches after beta decay to an excited state.