Conceptual Questions

31.1 Nuclear Radioactivity

1.

Suppose the range for 5.0 MeVα ray is known to be 2.0 mm in a certain material. Does this mean that every 5.0 MeVα a ray that strikes this material travels 2.0 mm, or does the range have an average value with some statistical fluctuations in the distances traveled? Explain.

2.

What is the difference between γ rays and characteristic x rays? Is either necessarily more energetic than the other? Which can be the most energetic?

3.

Ionizing radiation interacts with matter by scattering from electrons and nuclei in the substance. Based on the law of conservation of momentum and energy, explain why electrons tend to absorb more energy than nuclei in these interactions.

4.

What characteristics of radioactivity show it to be nuclear in origin and not atomic?

5.

What is the source of the energy emitted in radioactive decay? Identify an earlier conservation law, and describe how it was modified to take such processes into account.

6.

Consider Figure 31.3. If an electric field is substituted for the magnetic field with positive charge instead of the north pole and negative charge instead of the south pole, in which directions will the α, β , and γ rays bend?

7.

Explain how an α particle can have a larger range in air than a β particle with the same energy in lead.

8.

Arrange the following according to their ability to act as radiation shields, with the best first and worst last. Explain your ordering in terms of how radiation loses its energy in matter.

(a) A solid material with low density composed of low-mass atoms.

(b) A gas composed of high-mass atoms.

(c) A gas composed of low-mass atoms.

(d) A solid with high density composed of high-mass atoms.

9.

Often, when people have to work around radioactive materials spills, we see them wearing white coveralls (usually a plastic material). What types of radiation (if any) do you think these suits protect the worker from, and how?

31.2 Radiation Detection and Detectors

10.

Is it possible for light emitted by a scintillator to be too low in frequency to be used in a photomultiplier tube? Explain.

31.3 Substructure of the Nucleus

11.

The weak and strong nuclear forces are basic to the structure of matter. Why we do not experience them directly?

12.

Define and make clear distinctions between the terms neutron, nucleon, nucleus, nuclide, and neutrino.

13.

What are isotopes? Why do different isotopes of the same element have similar chemistries?

31.4 Nuclear Decay and Conservation Laws

14.

Star Trek fans have often heard the term "antimatter drive." Describe how you could use a magnetic field to trap antimatter, such as produced by nuclear decay, and later combine it with matter to produce energy. Be specific about the type of antimatter, the need for vacuum storage, and the fraction of matter converted into energy.

15.

What conservation law requires an electron's neutrino to be produced in electron capture? Note that the electron no longer exists after it is captured by the nucleus.

16.

Neutrinos are experimentally determined to have an extremely small mass. Huge numbers of neutrinos are created in a supernova at the same time as massive amounts of light are first produced. When the 1987A supernova occurred in the Large Magellanic Cloud, visible primarily in the Southern Hemisphere and some 100,000 light-years away from Earth, neutrinos from the explosion were observed at about the same time as the light from the blast. How could the relative arrival times of neutrinos and light be used to place limits on the mass of neutrinos?

17.

What do the three types of beta decay have in common that is distinctly different from alpha decay?

31.5 Half-Life and Activity

18.

In a 3×10^{9}-year-old rock that originally contained some ^{238}U, which has a half-life of 4.5×10^{9} years, we expect to find some ^{238}U remaining in it. Why are ^{226}Ra, ^{222}Rn, and ^{210}Po also found in such a rock, even though they have much shorter half-lives (1600 years, 3.8 days, and 138 days, respectively)?

19.

Does the number of radioactive nuclei in a sample decrease to *exactly* half its original value in one half-life? Explain in terms of the statistical nature of radioactive decay.

20.

Radioactivity depends on the nucleus and not the atom or its chemical state. Why, then, is one kilogram of uranium more radioactive than one kilogram of uranium hexafluoride?

21.

Explain how a bound system can have less mass than its components. Why is this not observed classically, say for a building made of bricks?

22.

Spontaneous radioactive decay occurs only when the decay products have less mass than the parent, and it tends to produce a daughter that is more stable than the parent. Explain how this is related to the fact that more tightly bound nuclei are more stable. (Consider the binding energy per nucleon.)

23.

To obtain the most precise value of BE from the equation $\mathrm{BE}=\left[\mathrm{ZM}\left({}^{1}\mathrm{H}\right)+\mathrm{Nm}_{n}\right]c^{2}-m\left({}^{A}X\right)c^{2}$, we should take into account the binding energy of the electrons in the neutral atoms. Will doing this produce a larger or smaller value for BE? Why is this effect usually negligible?

24.

How does the finite range of the nuclear force relate to the fact that BE/A is greatest for A near 60?

31.6 Binding Energy

25.

Why is the number of neutrons greater than the number of protons in stable nuclei having A greater than about 40, and why is this effect more pronounced for the heaviest nuclei?

31.7 Tunneling

26.

A physics student caught breaking conservation laws is imprisoned. She leans against the cell wall hoping to tunnel out quantum mechanically. Explain why her chances are negligible. (This is so in any classical situation.)

27.

When a nucleus α decays, does the α particle move continuously from inside the nucleus to outside? That is, does it travel each point along an imaginary line from inside to out? Explain.