**23.** How are artificial radioactive isotopes produced?
**24.** Neutrons are more effective for bombarding atomic nuclei than protons or alpha particles are. Why?
**25.** Why are all of the transuranium elements radioactive? (Hint: See Section 1.)

### PRACTICE PROBLEMS

**26.** The half-life of plutonium-239 is 24 110 years. Of an original mass of 100.g, how much plutonium-239 remains after 96 440 years? (Hint: See Sample Problem B.)
**27.** The half-life of thorium-227 is 18.72 days. How many days are required for three-fourths of a given amount of thorium-227 to decay?
**28.** Exactly $\frac{1}{16}$ of a given amount of protactinium-234 remains after 26.76 hours. What is the half-life of protactinium-234?
**29.** How many milligrams of a 15.0 mg sample of radium-226 remain after 6396 years? The half-life of radium-226 is 1599 years.

## *Nuclear Radiation*

### SECTION 3 REVIEW

**30.** Why can a radioactive material affect photographic film even though the film is well wrapped in black paper?
**31.** How does the penetrating ability of gamma rays compare with that of alpha particles and beta particles?
**32.** How does nuclear radiation damage biological tissue?
**33.** Explain how film badges, Geiger-Müller counters, and scintillation detectors are used to detect radiation and measure radiation exposure.
**34.** How is the age of an object that contains a radioactive nuclide estimated?

## *Nuclear Fission and Nuclear Fusion*

### SECTION 4 REVIEW

**35.** How is the fission of a uranium-235 nucleus induced?
**36.** How does the fission of uranium-235 produce a chain reaction?
**37.** Describe the purposes of the five major components of a nuclear power plant.
**38.** Describe the reaction that produces the sun's energy.
**39.** What is one problem that must be overcome before controlled fusion reactions that produce energy are a reality?

## MIXED REVIEW

**40.** Balance the following nuclear reactions:
a. $^{239}_{93}\text{Np} \longrightarrow {}^{0}_{-1}\beta + \underline{\ ?\ }$
b. $^{9}_{4}\text{Be} + {}^{4}_{2}\text{He} \longrightarrow \underline{\ ?\ }$
c. $^{32}_{15}\text{P} + \underline{\ ?\ } \longrightarrow {}^{33}_{15}\text{P}$
d. $^{236}_{92}\text{U} \longrightarrow {}^{94}_{36}\text{Kr} + \underline{\ ?\ } + 3\,{}^{1}_{0}n$

**41.** After 4797 years, how much of the original 0.250 g of radium-226 remains? The half-life of radium-226 is 1599 years.
**42.** The parent nuclide of the thorium decay series is $^{232}_{90}\text{Th}$. The first four decays are as follows: alpha emission, beta emission, beta emission, and alpha emission. Write the nuclear equations for this series of emissions.
**43.** The half-life of radium-224 is 3.66 days. What was the original mass of radium-224 if 0.0500 g remains after 7.32 days?
**44.** Calculate the neutron-proton ratios for the following nuclides, and determine where they lie in relation to the band of stability.
a. $^{235}_{92}\text{U}$ c. $^{56}_{26}\text{Fe}$
b. $^{16}_{8}\text{O}$ d. $^{156}_{60}\text{Nd}$

**45.** Calculate the binding energy per nucleon of $^{238}_{92}\text{U}$ in joules. The atomic mass of a $^{238}_{92}\text{U}$ nucleus is 238.050 784 amu.