CHAPTER 20 Review

REFLECTING ON CHAPTER 20

- The neutron was discovered by James Chadwick.
- The particles in the nucleus are called "nucleons" and consist of protons and neutrons. Their number is indicated by the atomic mass number (A).
- The number of protons in the nucleus is indicated by the atomic number (Z).
- In a neutral atom, the number of electrons orbiting the nucleus equals the number of protons in the nucleus.
- A common mass unit for atoms and nuclei is the atomic mass unit (u).

$$1 \text{ u} = 1.6605 \times 10^{-27} \text{ kg}$$

- The mass defect is the difference between the separate total mass of the nucleons and the mass of the nucleus. It represents the binding energy for that nucleus.
- Henri Becquerel discovered radioactivity.
- Radioactivity consists of the emission of alpha particles (helium nuclei), beta negative particles (high-speed electrons), beta positive particles (high-speed positrons), and gamma rays (photons).
- Alpha, beta, and gamma radiation vary in their mass, charge, penetrating ability, and possible biological damage. The passage of any of these rays through matter leaves ions behind, so the radiation is called "ionizing radiation."
- Radioactivity has many uses, both medical and non-medical. For example, it is commonly used in smoke detectors.
- During any nuclear reaction the total atomic mass number (A) and the total atomic number (Z) remain unchanged.
- Transmutation is the conversion of one element into another.
- The rate of radioactive decay is indicated by the half-life of the radioisotope.
- Radioactive decay rates can be used to determine the age of ancient materials.
- The amount of a radioactive isotope remaining after a given time interval can be determined by using the following equation.

$$N = N_0\left(\frac{1}{2}\right)^{\frac{\Delta t}{T_{\frac{1}{2}}}}$$

- The unit used to describe the rate of radioactive decay is the becquerel (Bq).
- Exposure to radiation can lead to various levels of sickness and, if severe enough, to death.

Knowledge/Understanding

1. Use Einstein's theory to explain how the term "mass defect" refers to an amount of energy.
2. Outline the rationale for postulating the existence of a strong nuclear force as one of the fundamental forces of nature.
3. Explain why, for stable nuclei with more than 40 nucleons, the ratio of neutrons to protons increases gradually as the number of nucleons increases.
4. Describe the characteristics of the three common forms of radioactivity.
5. Explain, based on our scientific understanding of radiation, why it is now useful to use the concept of a nucleon rather than a proton as a basic particle located in an atom's nucleus.

Inquiry

6. The concept of antimatter has stimulated the imagination of many science fiction writers. Research and prepare a report of the scientific discoveries that led to the inclusion of antimatter particles in scientific models of matter.
7. Insight into nuclear structure can be gained by considering the binding energy per nucleon, $\Delta E/A$, for different elements. Describe how the calculation of $\Delta E/A$ is used to indicate nucleons in a specific nucleus are tightly bound or loosely bound.

8. Suppose an experiment is designed to allow continuous observation of a single atom of a certain radioactive material. If the half-life is 1.5 h, can the observer predict when the atom will decay?

Communication

9. Explain why neutrons are said to make better "nuclear bullets" than either protons or electrons.

Making Connections

10. Food and surgical supplies are sometimes sterilized by radiation. What are the advantages and disadvantages of using this procedure rather than sterilization by heating?

11. Prepare a report on how radioactive tracers are used to either **(a)** follow the path of rainwater through groundwater reservoirs to lakes, streams, and wells or **(b)** map ocean currents.

Problems for Understanding

12. Determine the number of protons, neutrons and electrons in **(a)** a doubly ionized calcium ion $^{40}_{20}Ca^{++}$ **(b)** an iron atom $^{56}_{26}Fe$ **(c)** a singly charged chlorine ion $^{35}_{17}Cl^{-}$.

13. Calculate the binding energy for **(a)** $^{12}_{6}C$ with an atomic mass of 12.000 000 u **(b)** $^{133}_{55}Cs$ with an atomic mass of 132.905 429 u.

14. Write the equation for the alpha decay of thorium: $^{230}_{90}Th$.

15. What fraction of the original number of nuclei in a sample are left after **(a)** two half-lives, **(b)** four half-lives, and **(c)** 12 half-lives?

16. **(a)** How much energy is released when radium-226 (nuclear mass 225.977 09 u) alpha decays and becomes radon-222 (nuclear mass 221.970 356 u)? Answer in MeV. (An alpha particle has a mass of 4.001 506 u.)
    (b) If the nucleus was initially at rest, calculate the velocities of the alpha particle and the radon-222 nucleus in part (a).
    (c) What percentage of the total kinetic energy does the alpha particle carry away?

17. Hafnium-173 has a half-life of 24.0 h. If you begin with 0.25 g, how much will be left after 21 days?

18. How long will it take a 125 mg sample of krypton-89, which has a half-life of 3.16 min, to decrease to 10.0 μg?

19. A scientist at an archeological dig finds a bone that has a carbon-14 activity of 5.70×10^{-2} Bq. If the half-life of carbon-14 is 5.73×10^{3} a, what is the age of the bone? (Assume that the initial activity was 0.23 Bq.)

20. Suppose you began with a sample of 800 radioactive atoms with a half-life of 5 min.
    (a) How many atoms of the parent nucleus would be left after 10 min?
    (b) How many atoms of the daughter nucleus would be present after 10 min?
    (c) How many atoms of the parent nucleus would be left after 25 min?
    (d) How many atoms of the daughter nucleus would be present after 25 min?
    (e) Write an equation to determine the number of daughter nuclei present at any time.

21. In radioactive dating, ratios of the numbers of parent and daughter nuclei from the same decay chain, such as uranium-238 and lead-206, are determined. Assume that when the sample formed, it contained no daughter nuclei. Consider the analyses of three different rock samples that have been determined to have ratios of uranium-238 to lead-206 of 1.08:1, 1.22:1, and 1.75:1.
    (a) Using your answer to question 20. (e), write an equation for the ratio of the number of uranium-238 atoms to lead-206 atoms present at any time. (Hint: the initial number of uranium-238 atoms will divide out.)
    (b) Solve the above equation for time, and determine the ages of the three samples. (The half-life of uranium-238 is 4.5×10^{9} a.)
    (c) Explain whether these samples could have been taken from an area where the rock solidified all at once.
    (d) Intuitively, what conclusion can you draw if you measure a ratio of less than one?