1. Atomic Theory Describes Isotopes and Radioactive Decay
   - Radiation refers to high-energy rays and particles emitted by radioactive sources.
   - Isotopes are atoms of the same element that differ in the number of neutrons that they possess; isotopes of an element have the same atomic number but different mass number.
   - Radioisotopes are natural or human-made isotopes that decay into other isotopes, releasing radiation.
   - The three major types of radiation are alpha (helium nucleus), beta (fast-moving electron), and gamma (high-energy electromagnetic radiation).
2. A Half-Life Can Be Used to Describe the Rate of Radioactive Decay of an Isotope
   - All radioactive decay rates follow a similar pattern called a decay curve.
   - A half-life measures the time needed for half the radioisotopes in a sample to decay. The half-life is a constant that does not change regardless of the amount of a given radioisotope that is present.
   - Carbon dating is a method of absolute dating of the remains of organisms based on carbon-12 to carbon-14 ratios, to a maximum of 50 000 years in the past.
   - The Common Isotope Pairs Chart relates parent and daughter isotopes, half-life of parent and the effective dating range that a given isotope pair is useful for.
3. Nuclear Reactions Can Be Described as Fission or Fusion
   - Fission reactions cause changes to the nucleus involving the splitting of a more massive nucleus, releasing two lower mass nuclei as well as other particles and energy.
   - Fission reactions can be induced by colliding some large nuclei such as uranium-238 with neutrons or other small particles.
   - Fission reactions are used in nuclear powered generating stations (and were used in the first atomic weapons).
   - Fusion reactions are the result of two lower mass nuclei fusing to form a new, more massive one. Fusion reactions can release large amounts of energy.
   - The Sun's energy is produced through nuclear fusion reactions at its core, mostly involving isotopes of hydrogen.
   - Modern nuclear weapons use fission reactions involving uranium or plutonium to ignite fusion reactions involving hydrogen. The fusion reaction releases most of the energy.

CHAPTER REVIEW ANSWERS

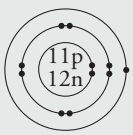
Checking Concepts

1. Radiation refers to high-energy rays and particles emitted by radioactive sources.
2. Radioisotopes are natural or human-made isotopes that decay into other isotopes, releasing radiation.
3. (a) Alpha, beta, gamma
   (b) Alpha particles are helium nuclei, beta particles are fast-moving electrons, and gamma rays are high-energy electromagnetic radiation.
   (c) Alpha particles have a 2+ charge, beta particles have a 1– charge, and gamma rays have no charge.
4. $^{4}_{2}\alpha$ or $^{4}_{2}\mathrm{He}$
5. (a) They have the same number of protons (12 each).
   (b) They have differing numbers of neutrons (12 and 14).
6. Proton
7. Protons and neutrons
8. A beta particle is an electron, which has a negative charge.
9. With the loss of an alpha particle, a nucleus loses two protons and two neutrons. With a different number of protons, the new nucleus is a different element.
10. (a) 

    (b) 

    (c) 

    (d) 

    (e) 

11.

Isotope	Mass Number	Atomic Number	Number of Neutrons
lithium-7	7	3	4
neon-22	22	10	12
silicon-29	29	14	15
sulfur-16	16	8	8
magnesium-24	24	12	12
magnesium-26	26	12	14

12. (a) 32 g
    (b) 8 g
13. Argon-40, the daughter isotope in the pair, is a gas. Melting the rock drives the argon-40 out of the material, leaving only potassium-40. This resets the clock to zero.
14. A nuclear reaction is a process in which an atom's nucleus changes by gaining or releasing particles or energy.
15. A nuclear reaction involves changes in the nucleus of atoms, while a chemical reaction involves changes in electron arrangements.
16. A nuclear equation is a set of symbols that describes the changes that occur during a nuclear reaction.
17. The total mass number and the total charge do not change during a nuclear reaction.
18. A nuclear reaction can be induced by making a nucleus unstable through bombardment with alpha particles, beta particles, or gamma rays.

Understanding Key Ideas

19. (a) Both are electromagnetic energy.
    (b) They have different wavelengths and energies.
20. Medical imaging and cancer treatments
21. Natural background radiation is the high-energy, fast-moving particles or waves found in our environment.
22. The number of protons in an atom is equal to the atomic number. The number of neutrons is equal to the mass number minus the atomic number.
23. (a) $^{201}_{81}\mathrm{Tl}$

    (b) $^{227}_{89}\mathrm{Ac}$

    (c) $^{221}_{87}\mathrm{Fr}$

    (d) $^{60}_{28}\mathrm{Ni}$

    (e) $^{234}_{90}\mathrm{Th}$

    (f) $^{24}_{12}\mathrm{Mg}$
24. Note: $^{4}_{2}\mathrm{He}$ can be used in place of $^{4}_{2}\alpha$ and $^{0}_{-1}e$ can be used in place of $^{0}_{-1}\beta$ in the following answers.

    (a) $^{50}_{23}\mathrm{V} \rightarrow {}^{46}_{21}\mathrm{Sc} + {}^{4}_{2}\alpha$

    (b) $^{40}_{18}\mathrm{Ar} \rightarrow {}^{40}_{19}\mathrm{K} + {}^{0}_{-1}\beta$

    (c) $^{3}_{2}\mathrm{He}^{*} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{0}_{0}\gamma$

    (d) $^{32}_{14}\mathrm{Si} \rightarrow {}^{28}_{12}\mathrm{Mg} + {}^{4}_{2}\mathrm{He}$

    (e) $^{26}_{13}\mathrm{Al}^{*} \rightarrow {}^{26}_{13}\mathrm{Al} + {}^{0}_{0}\gamma$

    (f) $^{36}_{17}\mathrm{Cl} \rightarrow {}^{36}_{18}\mathrm{Ar} + {}^{0}_{-1}e$

    (g) $^{33}_{15}\mathrm{P} \rightarrow {}^{29}_{13}\mathrm{Al} + {}^{4}_{2}\alpha$
25. Nitrogen-14
26. 5739 years
27. (a) 50 micrograms
    (b) 25 micrograms
    (c) 12.5 micrograms
28. (a) $^{156}_{58}\mathrm{Ce}$

    (b) $^{140}_{52}\mathrm{Te}$

    (c) $^{128}_{46}\mathrm{Pd}$
29. (a) Fission
    (b) Both
    (c) Fission
    (d) Fission
    (e) Fusion
    (f) Fusion

Applying Your Understanding

30. Accept all logical responses. For example, one might say that a fair coin toss is impossible to predict, as is identifying which specific nuclei will decay. On the other hand, in a coin toss, one could imagine that, with careful measurements, a successful prediction of how the coin will land could be made. No such prediction is possible for radioactive decay, even in principle.

Pause and Reflect Answer

Students should cover some of these points.

- Fission and fusion are both nuclear processes, which means they involve changes to the nuclei of atoms.