Solutions to Even-Numbered Exercises:

10.2 β-radiation is the emission of β particles that are electrons, with a charge of –1 and a mass of almost 0 amu.

10.4 Positrons have the same mass as electrons, but have a positive charge.

10.6 The sum of the mass numbers of the particles on the left must equal the mass numbers of the particles on the right; 238 + 12 = 249 + *x*, *x* = 1. Similarly, the atomic numbers of the particles on the left must equal the atomic numbers of the particles on the right; 92 + 6 = 98 + *y*, *y* = 0. Thus, the missing component must be a particle with a mass number of 1 and an atomic number of 0. This is a neutron, ${}^{1}_{0}\text{n}$.

10.8 The sum of the mass numbers of the particles on the left must equal the mass numbers of the particles on the right; 0 + *x* = 0, *x* = 0. Similarly, the atomic numbers of the particles on the left must equal the atomic numbers of the particles on the right; –1 + *y* = 0, *y* = +1. Thus, the missing component must be a particle with a mass number of 0 and an atomic number of +1. This is a positron, ${}^{0}_{+1}\text{e}$.

10.10 One example is ${}^{58}_{26}\text{Fe} + {}^{1}_{0}\text{n} \rightarrow {}^{59}_{26}\text{Fe}$

10.12 A daughter nucleus is the product isotope of a radioactive decay.

10.14 $\frac{N}{N_0} = \left(\frac{1}{2}\right)^x$, where *x* is the number of half-lives of C-14 that have passed.

$x = 2.75 \rightarrow (1/2)^{2.75} = 0.149$. Thus, 14.9% of the original C-14 is left in the sample.

10.16 β-radiation passes through solids fairly easily, yet has enough energy to damage tissue, therefore, it will produce long thin tracks of radiation damage in tissue.

10.18 As a γ-ray passes through tissue, it interacts with the tissue, loses energy, and its intensity is lowered.

10.20 γ-radiation will produce hydrated electrons that then undergo further reactions to produce hydrogen and hydroxyl free radicals.

10.22 The reaction of a free radical with a biomolecule may result in the change of the structure of an enzyme, which in turn will alter its ability to function properly.

10.24 Background radiation is a radiation that exists everywhere due to naturally occurring radioactive elements and radiation from outer space.

10.26 She could place a material through which the radiation cannot penetrate, such as a lead shield, between her and the radiation source.

10.28 A scintillation counter contains a material that emits a flash of light when struck by radiation. This light is monitored in a scintillation counter.

10.30 A rem is similar to a rad but it takes into account how different forms of radiation affect tissue differently.

10.32 Yes. γ-particles are as damaging to tissue (RBE ≈ 1.0) as β-particles (RBE ≈ 1.0), and thus the effect of 1 rad of γ-particles on tissue will be similar to that of β-particles.

10.34 Yes. In order to be used for diagnosis, the radiation must be detected outside the body. γ-particles penetrate tissue easily, and thus can be detected externally.

10.36 Yes. Radium-226 undergoes radioactive decay to emit γ-radiation that can easily penetrate tissue to cause radiation damage to the cancerous area.

10.38 No. β-particles are only detected indirectly by the presence of ions that are produced when β-particles interact with matter.

10.40 Yes. In order to be used for diagnosis, the radiation must be detected outside the body. γ-particles that are produced by technetium-99m can penetrate tissue easily and thus can be detected externally.

10.42 In a PET scan, an isotopically labeled compound is introduced into the body that undergoes radioactive decay, which emits a positron. The positron is short-lived as it reacts with any nearby electron. This reaction between an electron and a positron produces γ-radiation that is detected by the detector in the PET scan.

10.44 2.5 days = 60 hours. $\dfrac{60 \text{ hours}}{\frac{13.3 \text{ hours}}{1 \text{ half - life}}}$ = 4.51 half-lives.

$\dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^x$, where x = 4.51 → $(1/2)^{4.51}$ = 0.044, 0.044 × 10 ng = 0.44 ng remain

10.46 α-particle radiation is much more harmful to tissue than a β-emitter; this is accounted for by their RBE factors. α-particles have an RBE factor of 10, while β-emitters have an RBE factor of 1. Mathematically,

$$\frac{1 \text{ rad from } \alpha}{1 \text{ rad from } \beta} \times \frac{1 \text{ rad from } \beta}{1 \text{ rem from } \beta} \times \frac{10 \text{ rem from } \alpha}{1 \text{ rad from } \alpha} \times 15.2 \text{ mrem} = 152 \text{ mrem}$$

10.48 Going from 0.8 R to 0.2 R is decreasing the intensity by a factor of 4. As the intensity decreases by a factor that is inversely proportional to the square of the distance, to decrease the intensity by a factor of 4, the distance from the source must be doubled from 2 m to 4m.

10.50 When high-energy radiation interacts with tissue, the radiation breaks bonds or ionizes atoms or both.

10.52 No. The energy of infrared light is less than that of a covalent bond. Therefore, it cannot break a covalent bond and initiate chemical events.

10.54 No. The radioactivity dosage cannot be controlled if the radioactive product is as radioactive as the initial radioisotope. Also, in this case, the damage from the radioactivity cannot be controlled.

10.56 X-rays are high-energy photons.

10.58 Two of the chief problems in the production of X-rays are: (1) the generation of excessive heat at the cathode, and (2) the requirement for adequate shielding.

10.60 No. Only Bremsstrahlung can be used for medical imaging because its energy can be controlled.

10.62 X-rays are detected photographically or with the use of solid-state detectors.

10.64 The most practical solution is to first check with local health authorities to get their advice. In all likelihood, they will advise ventilating the basement and to install radon detection devices in the basement and attic.