α, β, and γ

1. See *Appendix A* for information about the word-processing files of the student experiments, as well as any other electronic resources available for this book.

2. Calculator users: If you are collecting data with TI graphing calculators, an application such as VST Apps or DataRad may need to be installed on the calculators. You can determine which app you need at www.vernier.com/til/2672

   The calculator instructions for this experiment are not intended for use with TI-Nspire handhelds or computer software. Radiation Monitors cannot be used with color-screen TI-84 Plus calculators (TI-84 Plus C Silver Edition and TI-84 Plus CE).

3. The absorption model students develop in the first few questions of the experiment is valid only in broad terms. The actual penetration of radiation can depend strongly on the energy of the particles, which is not considered in the simple reasoning applied here.

4. The Vernier Radiation Monitor, the Digital Radiation Monitor, and the Radiation Monitor are sensitive to all three types of radiation. The Student Radiation Monitor is not sensitive to alpha radiation, and so will not respond at all to the alpha source. Students doing this activity with the Student Radiation Monitor will thus not be able to study the relative absorption of alphas. See *Appendix B* for additional information about the different radiation monitors.

5. The three sources are commonly sold as small plastic discs, with the radioactive material embedded within the plastic. Note that the alpha source has an open window on the underside of the disc. Because alphas are so strongly absorbed, this open window must face the detector during the experiment.

6. Since the alpha source, polonium-210, has a half-life of 138 days, it must be replaced regularly. A source purchased years ago will be dead. You can test your source with the Vernier Radiation Monitor, the Digital Radiation Monitor, and the Radiation Monitor (but not the Student Radiation Monitor). Measure the background count in a 50 s interval. Place the open side of the source right next to the screen of the monitor, and measure the counts again. You should get at least three times the background count rate for a useable source.

7. The activity does not ask students to correct for background counts, since the count rate with sources will be so large. You may want to ask students to correct their measurements for the background counts.

8. Sources are available from these suppliers:
   - Spectrum Techniques: voice: (865) 482-9937, fax: (865) 483-0473, www.spectrumtechniques.com
   - Flinn Scientific: voice: (800) 452-1261, fax: (866) 452-1436, www.flinnsci.com

DATA TABLE

	No shielding	Paper shield	Aluminum shield
No source	15		
Alpha source	52	16	14
Beta source	10691	9904	24
Gamma source	4803	4503	2766

Note: If a Student Radiation Monitor is used, the alpha count rates will be zero.

ANSWERS TO PRELIMINARY QUESTIONS

1. Compared to betas and gammas, alpha particles are most likely to be absorbed by matter. We might expect that the absorption is large because they have the highest electrical charge, and for a given energy, are moving relatively slowly because of their large mass.

2. Compared to alphas and betas, gammas are least likely to be absorbed by matter. Again, we might expect that the absorption is smaller because they have no charge and move at the speed of light.

3. We expect beta radiation to be absorbed at a rate between that of alphas and gammas, since beta rays have less charge and move faster than alphas, and since gammas have no charge.

4. Compared to paper, the aluminum has the greater areal density. As a result, an aluminum sheet should be more strongly absorbing of radiation than a sheet of paper.

5. Answer will depend on the monitor used. The Vernier Radiation Monitor, the Digital Radiation Monitor, and the Radiation Monitor are sensitive to all three types; the Student Radiation Monitor is sensitive only to beta and gamma radiation.

ANSWERS TO ANALYSIS QUESTIONS

1. The count rate with no source (the background count rate) is much smaller than the count rate with a source. As a result, the correction is insignificant.

2. Yes, the data are consistent with predictions. Judging from the gamma data, the aluminum absorbs more than did the paper, which itself absorbed more than the thin layer of air between the source and the monitor. We expect that the alpha radiation would be most strongly absorbed, then beta, and finally gamma radiation would be the least absorbed. The alpha radiation was stopped by even one sheet of paper. The beta radiation was not stopped by the paper, but was stopped by the aluminum. The gamma radiation was strongly attenuated by the aluminum sheet, but passed easily through air and paper.

3. Since a relatively light aluminum sheet absorbed part of the gamma rays, a heavy lead apron should absorb much of the X-ray radiation. The apron thus shields the patient from X-ray exposure to the torso and pelvis.

ANSWERS TO EXTENSIONS

1. To determine the type of radiation (alpha, beta, or gamma), first determine the background count rate, then the source count rate with no absorber. Next, place a sheet of paper between the source and the monitor. If the counts are significantly reduced, the source emits alpha particles. If the count rate is not significantly reduced, place a 2 mm thick sheet of aluminum between the source and the monitor. If the count rate goes almost to the background level, the source is emitting beta particles. If the count rate is only reduced, the source is a gamma source.

2. One way to correct for background counts is to measure the background count rate several times to obtain an average value. Subtract this value from each of the other counts, replacing any negative numbers with zero. Some variation is to be expected with small count rates (see the "Counting Statistics" activity for more information). The background correction does not change any conclusions.