Radioactivity-2

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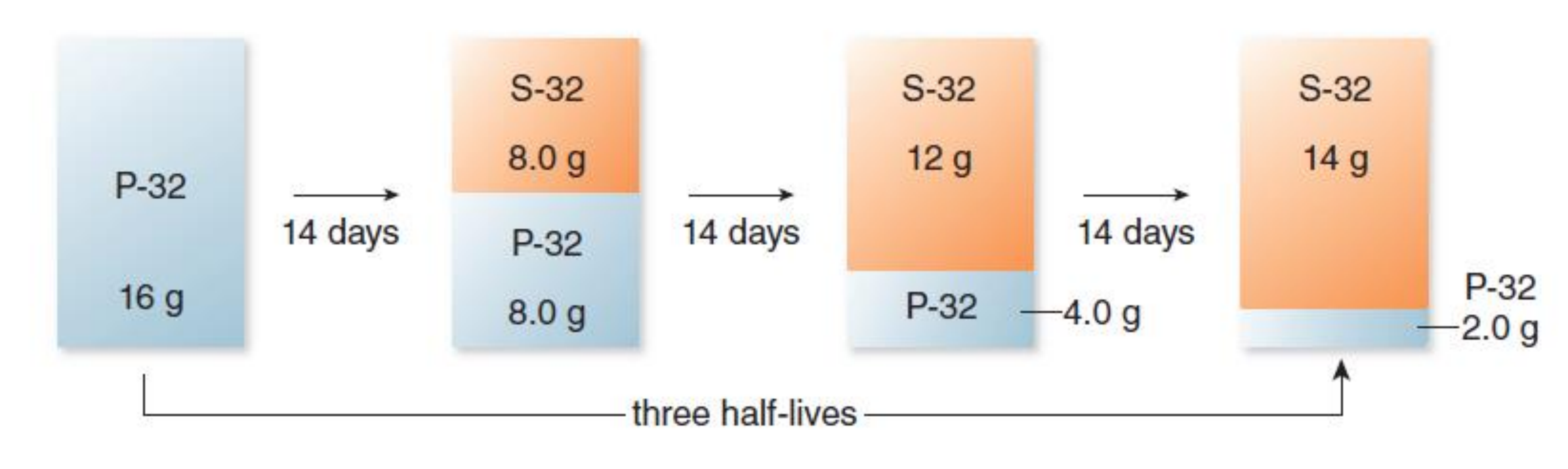
Lecture 9

5. Half-Life

- How fast do radioactive isotopes decay? It depends on the isotope.
- The half-life ($t_{1/2}$) **of a radioactive isotope is the time it takes for one-half of the sample to decay.**
- Suppose we have a sample that contains 16 g of phosphorus-32, a radioactive isotope that decays to sulfur-32 by β emission. Phosphorus-32 has a half-life of approximately 14 days. Thus, after 14 days, the sample contains only half the amount of P-32—8.0 g. After another 14 days (a total of two half-lives), the 8.0 g of P-32 is again halved to 4.0 g. After another14 days (a total of three half-lives), the 4.0 g of P-32 is halved to 2.0 g, and so on. Every 14 days, half of the P-32 decays.



Many naturally occurring isotopes have long half-lives. Examples include carbon-14 (5,730 years) and uranium-235 (7.0×10^8 years). Radioisotopes that are used for diagnosis and imaging in medicine have short half-lives so they do not linger in the body. Examples include technetium-99m (6.0 hours) and iodine-131 (8.0 days). **The half-life of a radioactive isotope is a property of a given isotope and is independent of the amount of sample, temperature, and pressure.**

6. Detecting and Measuring Radioactivity

- We all receive a miniscule daily dose of radiation from cosmic rays and radioactive substances in the soil. Additional radiation exposure comes from television sets, dental X-rays, and other man-made sources.
- **How can radiation be detected and measured when it can't be directly observed by any of the senses?**
- A Geiger counter is a small portable device used for measuring radioactivity. It consists of a tube filled with argon gas that is ionized when it comes into contact with nuclear radiation. This in turn generates an electric current that produces a clicking sound on a meter. Geiger counters are used to locate a radiation source or a site that has become contaminated by radioactivity.

6. Detecting and Measuring Radioactivity

- The amount of radioactivity in a sample is measured by the number of nuclei that decay per unit time-disintegrations per second. **The most common unit is the curie (Ci)**, and smaller units derived from it, the millicurie (mCi) and the microcurie (μCi). One curie equals 3.7×10^{10} disintegrations/second, which corresponds to the decay rate of 1 g of the element radium.
- The becquerel (Bq), an SI unit, is also used to measure radioactivity; 1 Bq = 1 disintegration/second. Since each nuclear decay corresponds to one becquerel, 1 Ci = 3.7×10^{10} Bq.

Table 9.3 Units Used to Measure Radioactivity

1 Ci = 3.7×10^{10} disintegrations/s
1 Ci = 3.7×10^{10} Bq
1 Ci = 1,000 mCi
1 Ci = 1,000,000 μCi

PROBLEM

A patient must be given a 4.5-mCi dose of iodine-131, which is available as a solution that contains 3.5 mCi/mL. What volume of solution must be administered?

The curie is named for Polish chemist Marie Skłodowska Curie who discovered the radioactive elements polonium and radium, and received Nobel Prizes for both Chemistry and Physics in the early twentieth century.

7. Medical Uses of Radioisotopes

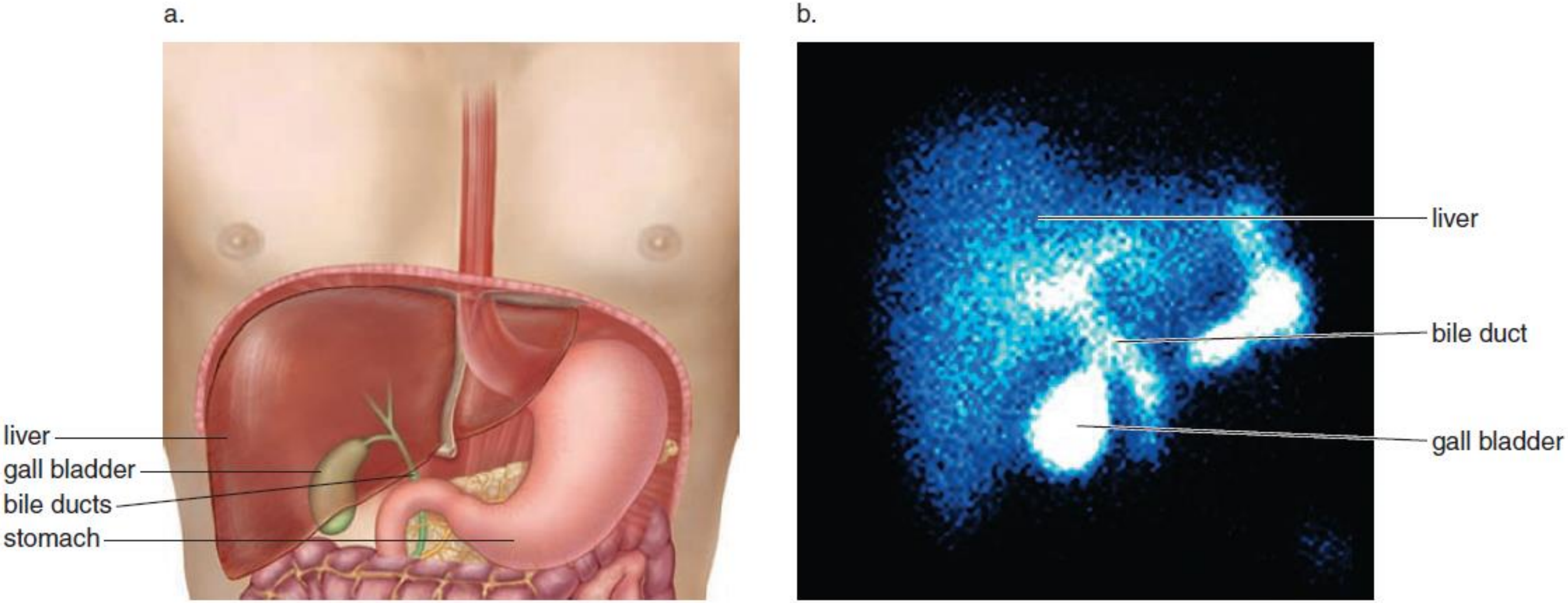
- Radioactive isotopes are used for both diagnostic and therapeutic procedures in medicine.

7.1. Radioisotopes Used in Diagnosis

- Radioisotopes are routinely used to determine if an organ is functioning properly or to detect the presence of a tumor. The isotope is ingested or injected and the radiation it emits can be used to produce a scan.
- The radioactive atom is bonded to a larger molecule that targets a specific organ. An organ that has increased or decreased uptake of the radioactive element can indicate disease, the presence of a tumor, or other conditions.

- A HIDA scan (hepatobiliary iminodiacetic acid scan) uses a technetium-99m-labeled molecule to evaluate the functioning of the gall bladder and bile ducts After injection, the technetium-99m travels through the bloodstream and into the liver, gall bladder, and bile ducts, where, in a healthy individual, the organs are all clearly visible on a scan. When the gall bladder is inflamed or the bile ducts are obstructed by gallstones, uptake of the radioisotope does not occur and these organs are not visualized because they do not contain the radioisotope.
- Red blood cells tagged with technetium-99m are used to identify the site of internal bleeding in an individual.
- Bone scans performed with technetium-99m can show the location of metastatic cancer, so that specific sites can be targeted for radiation therapy.

Figure 9.4 HIDA Scan Using Technetium-99m

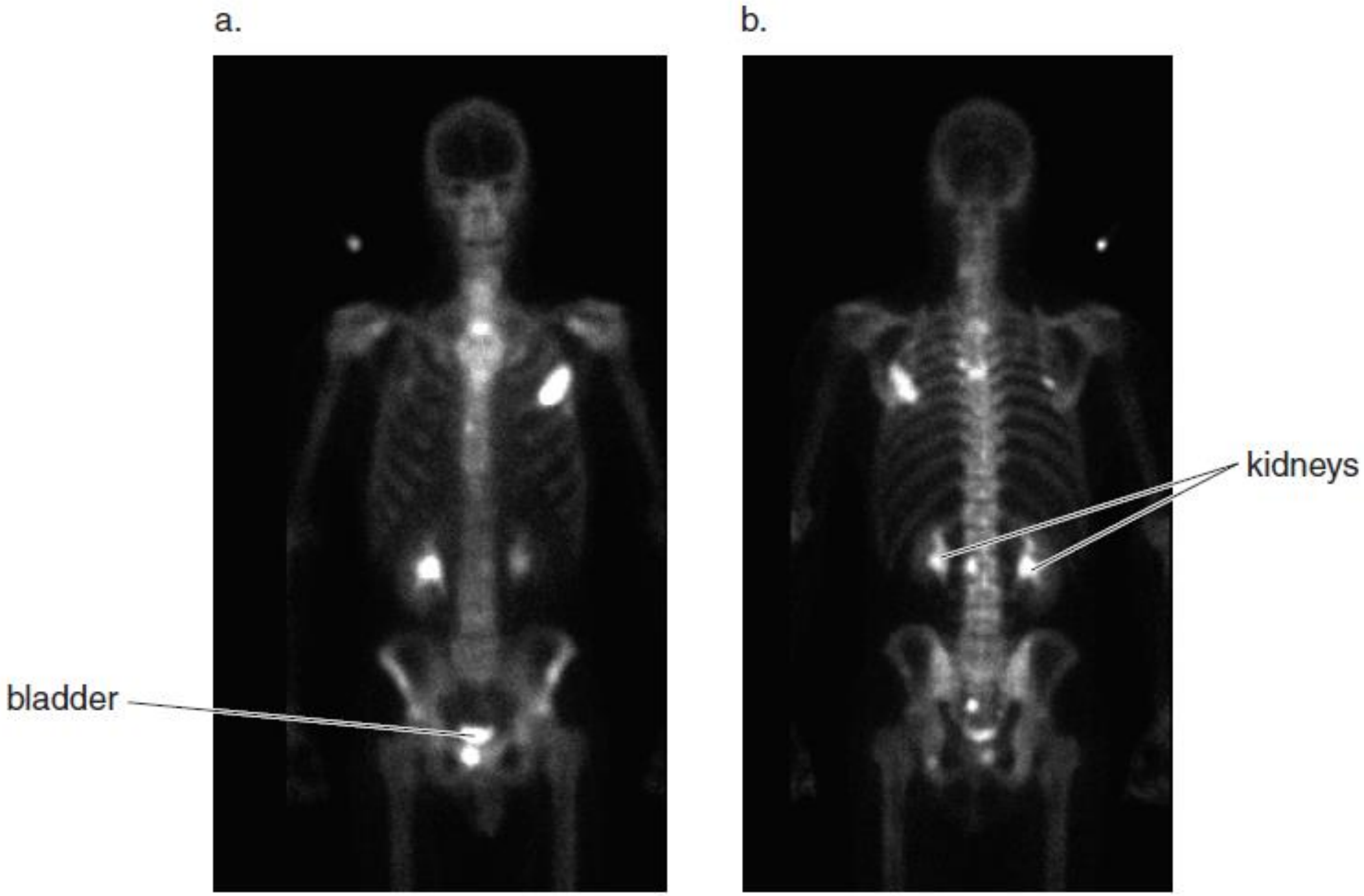


a. Schematic showing the location of the liver, gall bladder, and bile ducts

b. A scan using technetium-99m showing bright areas for the liver, gall bladder, and bile ducts, indicating normal function

Figure 9.5

Bone Scan Using Technetium-99m



The bone scan of a patient whose lung cancer has spread to other organs. The anterior view [from the front in (a)] shows the spread of disease to the ribs, while the posterior view [from the back in (b)] shows spread of disease to the ribs and spine. The bright areas in the mid-torso and lower pelvis are due to a collection of radioisotope in the kidneys and bladder, before it is eliminated in the urine.

7.2. Radioisotopes Used in Treatment

- The high-energy radiation emitted by radioisotopes can be used to kill rapidly dividing tumor cells. Two techniques are used. Sometimes the radiation source is external to the body.
- For example, a beam of radiation produced by decaying cobalt-60 can be focused at a tumor. Such a radiation source must have a much longer half-life—5.3 years in this case—than radioisotopes that are ingested for diagnostic purposes. With this method some destruction of healthy tissue often occurs, and a patient may experience some signs of radiation sickness, including vomiting, fatigue, and hair loss.

8. Medical Imaging Without Radioactivity

- **X-rays, CT scans**, and **MRIs** are also techniques that provide an image of an organ or extremity that is used for diagnosis of a medical condition. Unlike PET scans and other procedures discussed thus far, however, these procedures are not based on nuclear reactions and they do not utilize radioactivity. In each technique, an energy source is directed towards a specific region in the body, and a scan is produced that is analyzed by a trained medical professional.

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