Module 14

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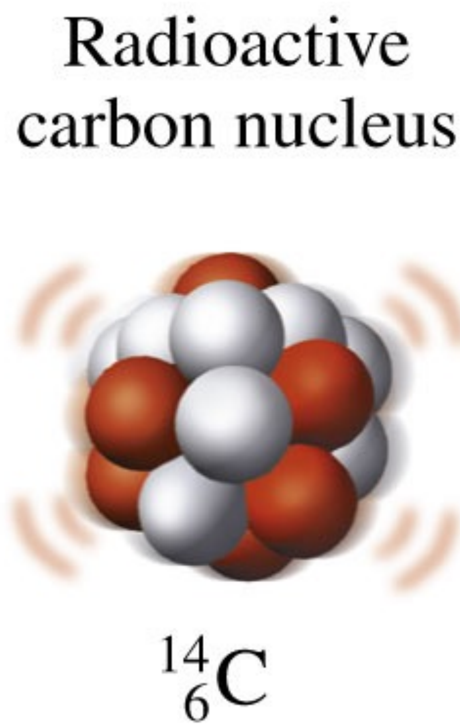
BIOC 141

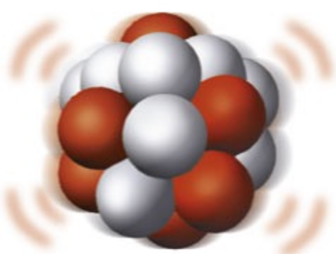
Radioactivity (Section 10.1)



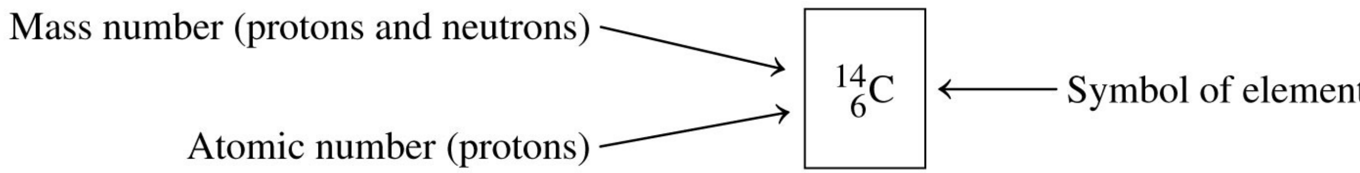
An unstable nucleus is radioactive, which may spontaneously emit small particles of energy called radiation to become more stable.

Radioactivity

Radioactive carbon nucleus



$^{14}_{6}C$



Carbon-14 is a radioactive isotope used in archaeological dating

Types of Radiation

- alpha (α) particles, identical to a helium nucleus
- beta (β) particles, high-energy electrons
- positrons (β^+)
- pure energy called gamma (γ) rays

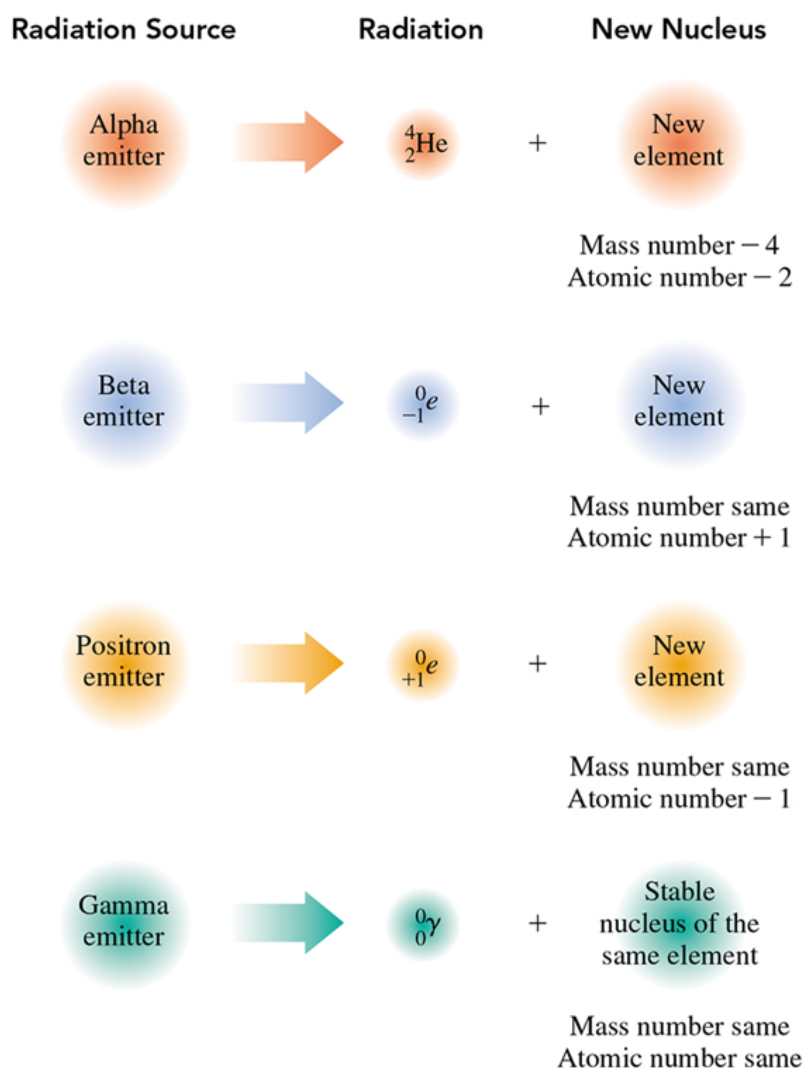
Alpha particle	${}^{4}_{2}\mathrm{He}$ or α	Positron	${}^{0}_{+1}e$ or β^{+}
Beta particle	${}^{0}_{-1}e$ or β	Gamma ray	${}^{0}_{0}\gamma$ or γ

Concept Check

Give the mass number and charge
of each type of radiation

	Mass Number	Charge
A. alpha particle		
B. positron		
C. beta particle		
D. gamma ray		

Nuclear Equations



Biological Effects of Radiation

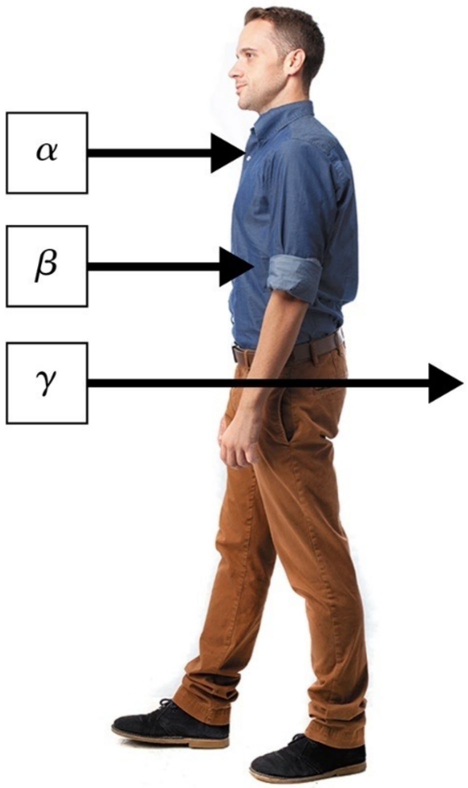
Ionizing radiation strikes molecules in its path.

- It damages the cells most sensitive to radiation: rapidly dividing cells in bone marrow, skin, and reproductive organs, and cancer cells.
- Cancer cells are highly sensitive to radiation; large doses of radiation are used to destroy them.
- The normal tissue around cancer cells divides at a slower rate and suffers less damage from radiation.
- Radiation may cause malignant tumors, leukemia, anemia, and genetic mutations.

Radiation Protection

- paper and clothing for alpha particles
- a lab coat or gloves for beta particles
- a lead shield or thick concrete wall for gamma rays
- limiting the amount of time spent near a radioactive source
- increasing the distance from the source

Radiation Protection



Different types of radiation penetrate the body to different depths.

In a nuclear pharmacy, a person working with radioisotopes wears protective clothing and gloves and uses a lead glass shield.

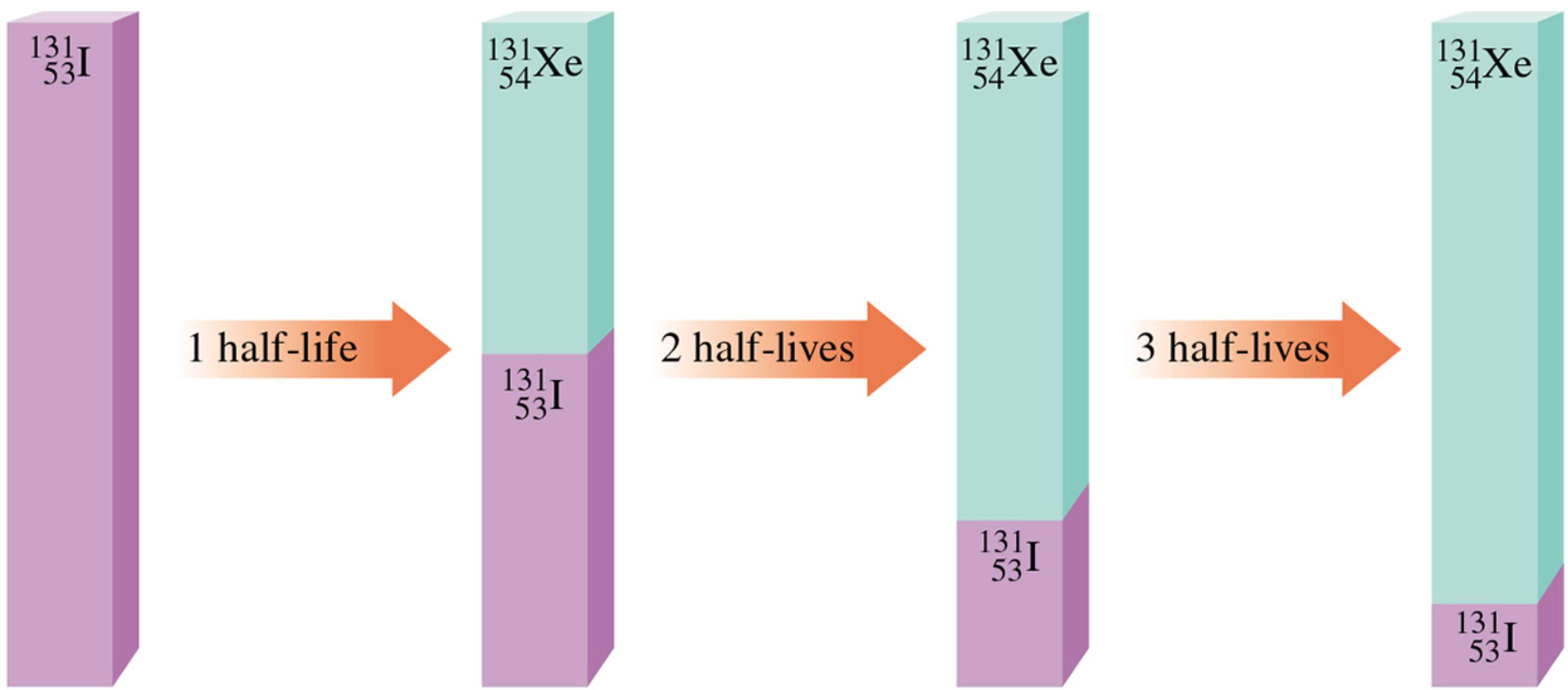
Concept Check

Indicate the type of radiation (alpha, beta, and/or gamma) protection for each type of shielding.

A. heavy clothing
B. paper
C. lead
D. lab coat
E. thick concrete

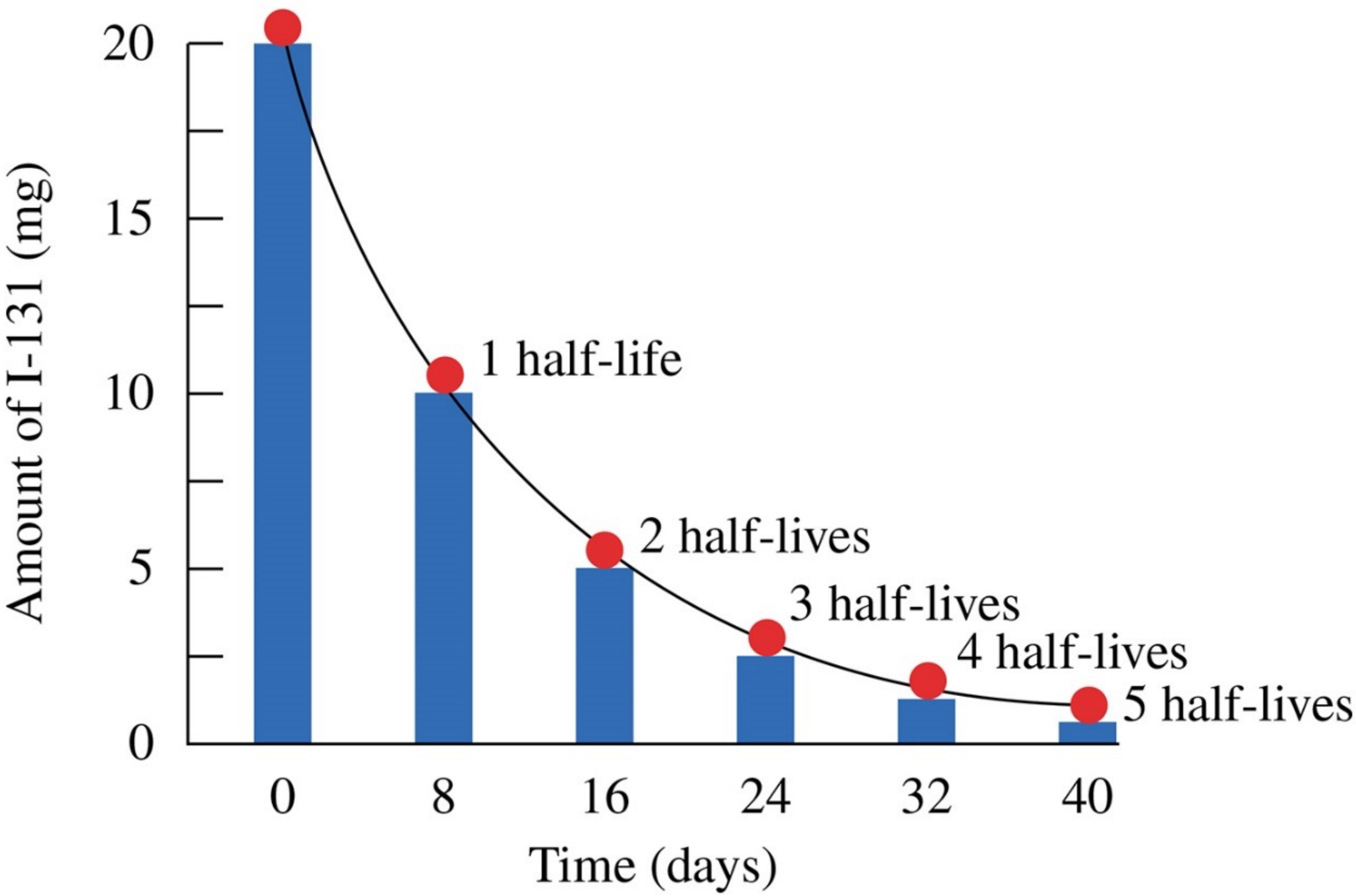
Half Life

The half-life of a radioisotope is the time for the radiation level (activity) to decrease (decay) to one-half of its original value.



$$20.\ \text{mg of } ^{131}_{53}\text{I} \xrightarrow{\text{1 half-life}} 10.\ \text{mg of } ^{131}_{53}\text{I} \xrightarrow{\text{2 half-lives}} 5.0\ \text{mg of } ^{131}_{53}\text{I} \xrightarrow{\text{3 half-lives}} 2.5\ \text{mg of } ^{131}_{53}\text{I}$$

Decay curve


20
15
10
5
0
Amount of I-131 (mg)
1 half-life
2 half-lives
3 half-lives
4 half-lives
5 half-lives
0
8
16
24
32
40
Time (days)

Half-Lives of Radioisotopes

TABLE 5.7 Half-Lives of Some Radioisotopes

Element	Radioisotope	Half-Life	Type of Radiation
Naturally Occurring Radioisotopes			
Carbon-14	${}^{14}_{6}C$	5730 yr	Beta
Potassium-40	${}^{40}_{19}K$	1.3×10^9 yr	Beta, gamma
Radium-226	${}^{226}_{88}Ra$	1600 yr	Alpha
Strontium-90	${}^{90}_{38}Sr$	38.1 yr	Alpha
Uranium-238	${}^{238}_{92}U$	4.5×10^9 yr	Alpha
Some Medical Radioisotopes			
Carbon-11	${}^{11}_{6}C$	20. min	Positron
Chromium-51	${}^{51}_{24}Cr$	28 days	Gamma
Iodine-131	${}^{131}_{53}I$	8.0 days	Gamma
Oxygen-15	${}^{15}_{8}O$	2.0 min	Positron
Iron-59	${}^{59}_{26}Fe$	44 days	Beta, gamma
Radon-222	${}^{222}_{86}Rn$	3.8 days	Alpha
Technetium-99m	${}^{99m}_{43}Tc$	6.0 h	Beta, gamma

Example

The radioisotope strontium-90 has a half-life of 38.1 years. If a sample contains 36 mg of Sr-90, how many milligrams will remain after 114.3 yr?

Concept Check

Iodine-123, used in the treatment of thyroid, brain, and prostate cancer, has a half-life of 13.2 h. How much of a 64-mg sample of I-123 is left after 26.4 hours?

Radiation Measurement

A radiation counter is used to check radiation levels at the Fukushima Daiichi nuclear power plant

Dosimeters for Exposure

People who work in radiation laboratories wear dosimeters attached to their clothing.

Dosimeters detect the amount of radiation exposure from:

- X-rays
- gamma rays
- beta particles

Units for Measuring Radiation

- curie (Ci) - the number of disintegrations that occurs in 1 s for 1 g of radium.
- becquerel (Bq) - the SI unit of radiation activity.
- rad (radiation absorbed dose) - measures the amount of radiation absorbed by a gram of material such as body tissue
- rem (radiation equivalent in humans) - measures biological effects of different kinds of radiation

Medical Application of Radioactivity

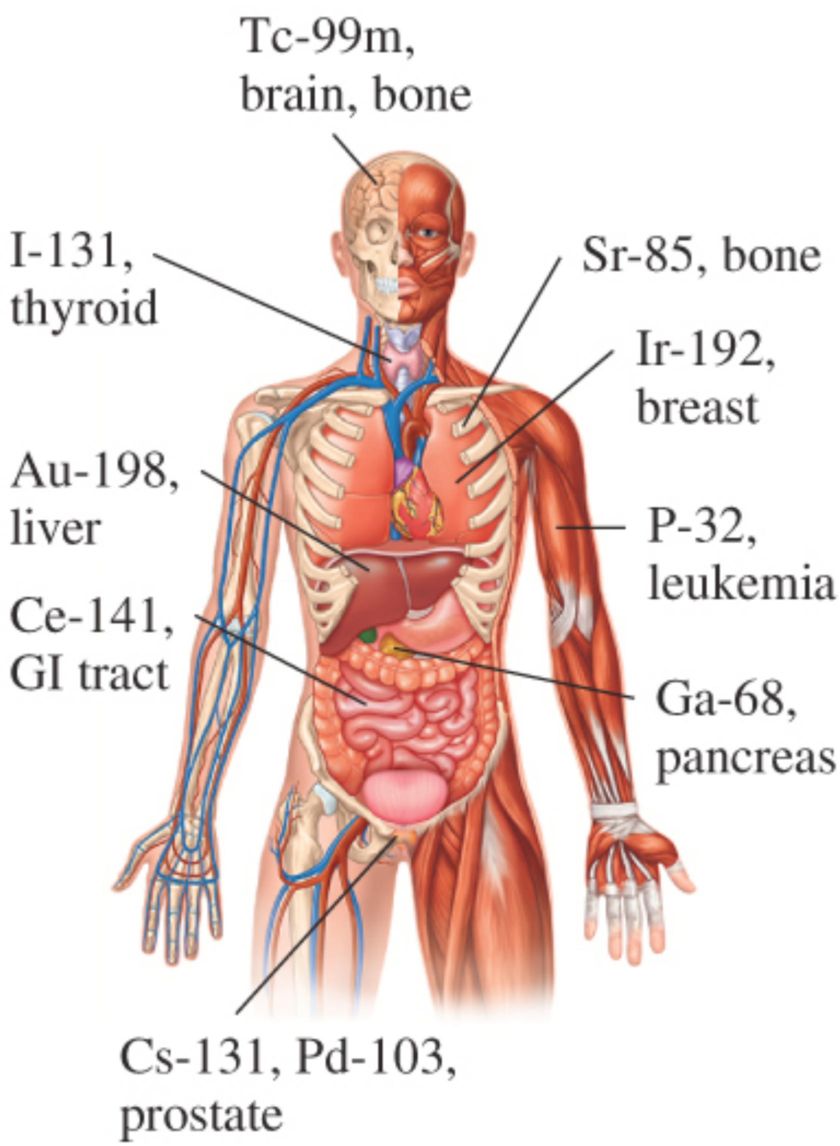


TABLE 5.8 Medical Applications of Radioisotopes

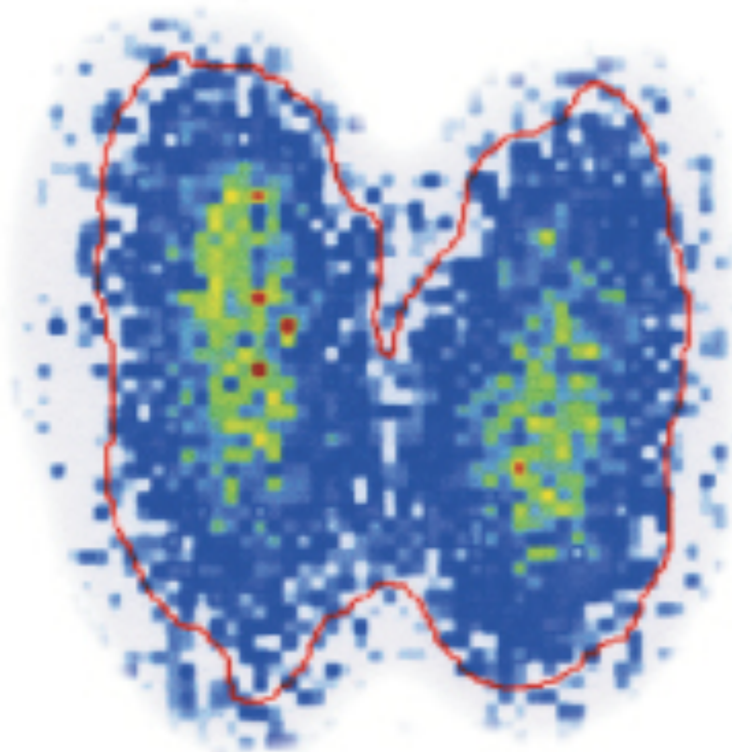
Isotope	Half-Life	Radiation	Medical Application
Au-198	2.7 days	Beta	Liver imaging; treatment of abdominal carcinoma
Ce-141	32.5 days	Beta	Gastrointestinal tract diagnosis; measuring blood flow to the heart
Cs-131	9.7 days	Gamma	Prostate brachytherapy
F-18	110 min	Positron	Positron emission tomography (PET)
Ga-67	78 h	Gamma	Abdominal imaging; tumor detection
Ga-68	68 min	Gamma	Detection of pancreatic cancer
I-123	13.2 h	Gamma	Treatment of thyroid, brain, and prostate cancer
I-131	8.0 days	Beta	Treatment of Graves' disease, goiter, hyperthyroidism, thyroid and prostate cancer
Ir-192	74 days	Gamma	Treatment of breast and prostate cancer
P-32	14.3 days	Beta	Treatment of leukemia, excess red blood cells, and pancreatic cancer
Pd-103	17 days	Gamma	Prostate brachytherapy
Sm-153	46 h	Beta	Treatment of bone cancer
Sr-85	65 days	Gamma	Detection of bone lesions; brain scans
Tc-99m	6.0 h	Gamma	Imaging of skeleton and heart muscle, brain, liver, heart, lungs, bone, spleen, kidney, and thyroid; most widely used radioisotope in nuclear medicine
Xe-133	5.2 days	Beta	Pulmonary function diagnosis
Y-90	2.7 days	Beta	Treatment of liver cancer

Scans with Radioisotopes

After the patient receives a radioisotope,

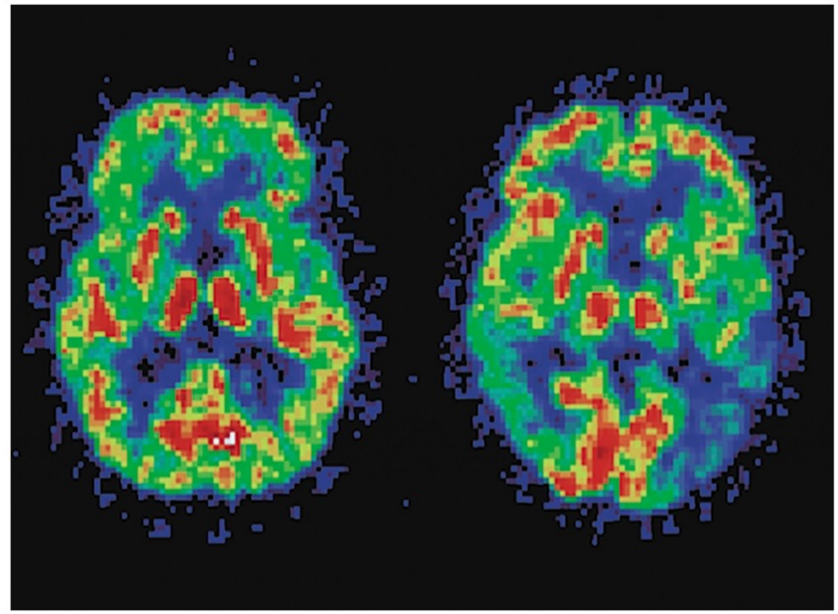
- the scanner moves slowly across the body above the region where the organ containing the radioisotope is located
- the radiation technologist determines the level and location of radioactivity emitted by the radioisotope
- the gamma rays emitted from the radioisotope can be used to expose a photographic plate, producing a scan of the organ

Thyroid Scan (iodine-131 accumulation)



Positron Emission Tomography

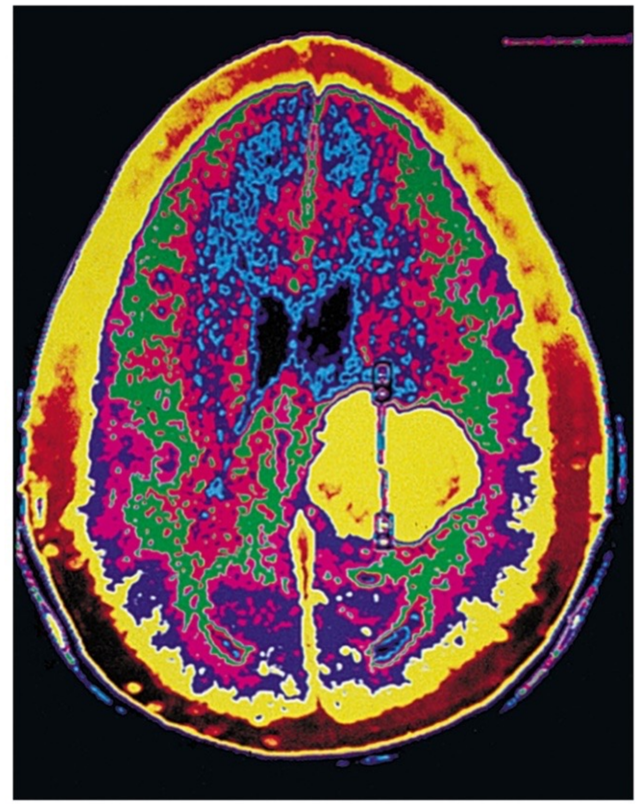
- Positron emitters with short half-lives are combined with body substances such as glucose
- Positrons are used to study brain function, metabolism, and blood flow



These PET scans show a normal brain on the left and a brain affected by Alzheimer's disease on the right.

Computerized Tomography

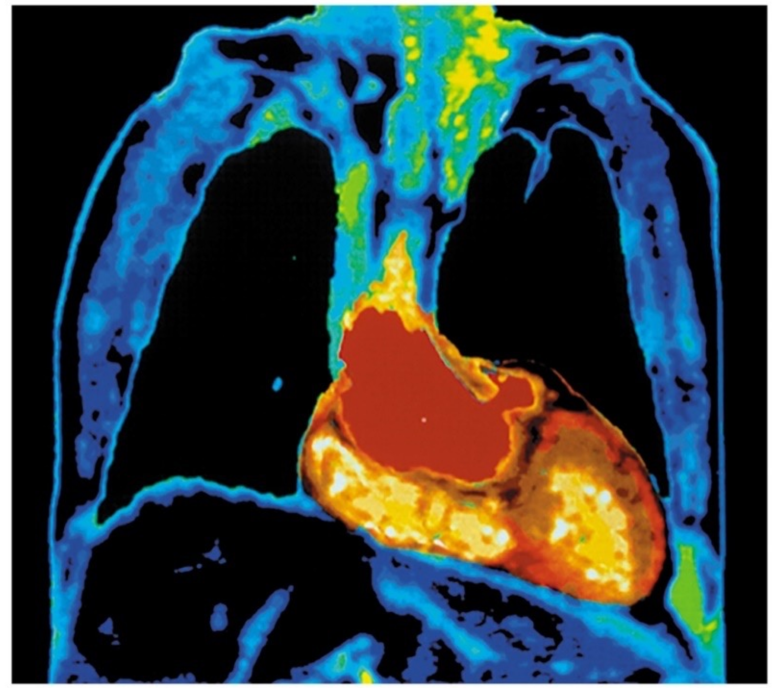
- A computer monitors the absorption of 30 000 X-ray beams directed at successive layers of the target organ
- Based on the densities of the tissues and fluids in the organ, the differences in absorption of the X-rays provide a series of images of the organ



A CT scan shows a tumor (yellow) in the brain

Magnetic Resonance Imaging

- Imaging technique that does not involve X-ray radiation
- Least invasive imaging method available
- Based on the absorption of energy when protons in hydrogen atoms are excited by a strong magnetic field



An MRI scan provides images of the heart and lungs