Uses for Radioactive Nuclides

- Cancer radiation treatment
- Computer imaging techniques
- Radiocarbon dating
- Smoke detectors
- Food irradiation to improve shelf life of foods such as potatoes, onions, and strawberries

Uses for Cobalt-60

- Cobalt-60 has many uses, including in cancer treatment, to sterilize insect pests, irradiate food to increase shelf life, and sterilize medical instruments.
- It is produced from iron-58.

$$^{58}_{26}\mathrm{Fe} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{59}_{26}\mathrm{Fe}$$

$$^{59}_{26}\mathrm{Fe} \rightarrow {}^{59}_{27}\mathrm{Co} + {}^{0}_{-1}\mathrm{e}$$

$$^{59}_{27}\mathrm{Co} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{60}_{27}\mathrm{Co}$$

Radiation Treatment for Cancer

- Cobalt-60 emits beta particles accompanied by gamma rays.

$$^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{Ni} + {}^{0}_{-1}\mathrm{e} + \gamma\text{-photon}$$

- The patient is easily shielded from the beta particles, which do not penetrate the skin, but the gamma rays are highly penetrating.
- Gamma ray beams from several directions intersect at tumor so tumor gets more radiation than healthy tissue.
- Damages DNA and kills cells

Linear Accelerator Treatment for Cancer

- Replaced to some degree by linear accelerators that accelerate high-energy x-rays, electrons, or protons that can be focused on the tumor.
- It does not involve radioactive substances.

Magnetic Resonance Imaging (MRI)

- Protons in hydrogen atoms act like tiny magnets.
- When patients are put in the strong magnetic field, the proton magnets in their hydrogen atoms line up either with or against the field (called parallel and anti-parallel).

Magnetic Resonance Imaging (MRI)

- Parallel alignment is slightly more stable than antiparallel. The difference is energy is small.
- Relatively low energy radio waves can excite the protons from parallel to antiparallel alignment.

  parallel + radio wave photons → anti-parallel
- The protons shift back to the more stable parallel arrangement.

  anti-parallel → parallel + emitted energy
- Emitted energy is detected by scanners placed around the patient's body.

MRI Imaging

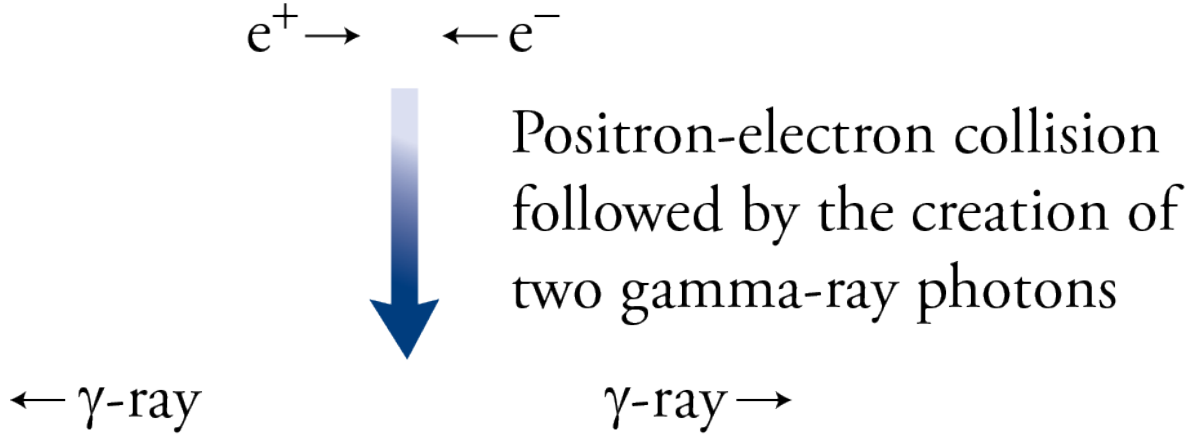
- Soft tissues contain a lot of water (with a lot of hydrogen atoms) and bones do not, so the MRI process is especially useful for creating images of the soft tissues of the body.

Positron Emission Tomography (PET Scan)

- It has a variety of research and clinical uses, including
  - creating images of tumors,
  - diagnosing brain diseases,
  - and studying normal brain and heart function.

Positron Emission Tomography (PET Scan)

- A solution containing a positron-emitting substance is introduced into the body. The positrons collide with electrons, and the two species annihilate each other, creating two gamma photons that move apart in opposite directions.



Positron Emission Tomography (PET Scan)

- The gamma photons are detected, and the data analyzed by a computer to yield images.
- Different nuclides are used to study different parts of the body. For example,
  - Fluorine-18 for tumor imaging
  - Glucose with carbon-11 for the brain
  - Oxygen-15 to study blood flow

Radiocarbon Dating

[If not for radiocarbon dating,] we would still be floundering in a sea of imprecisions sometimes bred of inspired guesswork but more often of imaginative speculations.

Desmond Clark, Anthropologist

- Dating to about 50,000 years
- Natural carbon is 98.89% carbon-12, 1.11% carbon-13, and 0.00000000010% carbon-14, which comes from

$$^{14}_{7}\mathrm{N} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{14}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H}$$

Radiocarbon Dating (2)

- Carbon-14 is oxidized to CO_2, which is then converted into substances in plants, which are then eaten by animals.
- Carbon-14 is a beta emitter with a half-life of 5730 years (±40 years), so as soon as it becomes part of a plant or animal, it begins to disappear.

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$$

Radiocarbon Dating (3)

- When alive, intake of ^{14}C balances the decay, so ratio of ^{14}C to ^{12}C remains constant at about 1 in 1,000,000,000,000.
- When the plant or animal dies, it stops taking in fresh carbon, but the ^{14}C it contains continues to decay. Thus the ratio of ^{14}C to ^{12}C drops steadily.
- The $^{14}C/^{12}C$ ratio in the sample is used to calculate its age.

Radiocarbon Dating (4)

- Assuming that the $^{14}C/^{12}C$ ratio has been constant over time, if the $^{14}C/^{12}C$ ratio in a sample is one-half of the ratio found in the air today, the object would be about 5730 years old. A $^{14}C/^{12}C$ ratio of one-fourth of the ratio found in the air today would date it as 11,460 years old (2 half-lives), etc.
- It's not that simple…the percentage of ^{14}C in the air varies due to factors such as volcanoes and natural variations in cosmic radiation.

Radiocarbon Dating (5)

- Tree rings show that the $^{14}C/^{12}C$ ratio has varied by about $\pm 5\%$ over the last 1500 years.
- Very old trees, such as the bristlecone pines in California, yield calibration curves for radiocarbon dating to about 10,000 years, which allow more precise dating of objects.