Radioactivity

- Emission of high energy photons and particles

Alpha, Beta and Gamma Rays

- Elements heavier than lead (Z=82), are radioactive
- Radioactive materials emit:
  - alpha particles (helium nucleus)
  - beta particles (electrons)
  - gamma rays (electromagnetic radiation)

How can we tell the difference between these?

Remember the Periodic Table?

Penetrating power is different for the different radioactive “particles” emitted

Lead is the best shield as it is the densest. This is also why your dentist makes you wear a lead vest when you get your teeth X-ray’d.

Watch Out!

Practical Uses

Gamma-rays can kill micro-organisms helping to keep food fresh longer

Strawberries themselves are unharmed
Gamma-rays can kill cancerous tumors
Radiation therapy has saved millions of lives

Practical Uses

Big nuclei are unstable due to the limited range of the strong force that holds them together

Why are some materials Radioactive?

Unstable

Stable

(a) Nucleons close together
(b) Nucleons far apart

What Happens?

Uranium 238 spontaneously decays to Thorium 234 and an alpha particle

What is this transmutation of heavy to light elements called?

Thorium 234 decays to Protactinium and a beta particle

What Happens?

Carbon-14 (with two “extra” neutrons”) is also unstable and will decay into Nitrogen and an electron

What Happens?

Uranium 238 spontaneously decays to Thorium 234 and an alpha particle
Thorium decays to Protactinium and so on, all the way down to lead
Various byproducts are alpha, beta and gamma radiation
Particles (and gamma rays) leave the nucleus with a lot of energy (high speed)
Bombardment of nuclei with high energy particles can increase the number of unstable isotopes. Some Materials can become radioactive:

Radioactive waste products:
- HIGH: spent fuel rods
- low: containment materials, pipes, suits

Current total US waste: 100 million gallons + 2500 tons solid waste

Yucca Mountain:
- 80 miles North of Las Vegas
- Studies began in 1978
- Under construction since 2002
- $9 Billion spent so far
- Considerable opposition
- Planned to open in 2020

How Fast?

It's an "exponential" decay
Half of the radioactive material will transmute in a set amount of time
This amount of time is called the "half-life"

Half-life for radium 226 is 1620 y

Radioactive Dating

All living things contain trace elements of radioactive C-14
After they die the C-14 levels gradually diminish due to radioactive decay of the C-14 with a half-life of 5730 years
At creation rubidium and strontium are equal.
Rubidium-87 decays to strontium-86 with a half-life of 49 billion years.

Nuvvuagittuq greenstone belt, exposed on the eastern shore of Hudson Bay in northern Quebec. 4.28 billion y old.

Clicker Question:
The half-life of Carbon-14 is roughly 6000 years. How old is a skeleton that contains only 12.5% of its original C-14?
A: 3000 years
B: 6000 years
C: 12000 years
D: 18000 years

When a heavy element like Uranium decays to a lighter element like Thorium, what do we call it?
A: Fusion
B: Fission
C: Transmogrification
D: Uranicide

Common rocks and minerals contain small amounts of radioactive isotopes.
- Radon gas is radioactive and may accumulate in basements.
- Burning coal releases 13,000 tons of Th and Ur annually.
- Nuclear power plants generate 10,000 tons of radioactive waste annually.
- Flying on airplanes results in higher exposures to gamma-rays.
- Medicine and diagnostics (e.g., X-rays).

Environmental Radiation - Dosage
Common measure is rad (radiation absorbed dose).
1 rad = 0.01 joules/kg

Unit of measure for damage is rem (roentgen equivalent man).
Normal annual exposure: 300 millirems (mrem).
Bonus exposure on commercial airline in US: 0.25 mrem/hour.
Bonus exposure flying the polar route: 3 mrem/hour.
Bonus exposure from an X-ray: 40 mrem.
Fatal instantaneous dosage: 500 rems (500,000 mrems).

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300 mrems total
Natural background 75% (cosmic rays, Earth minerals, radon in air)
Consumer products 2% (TV, monitors, smoke detectors)
Coal and nuclear power plants, weapons tests fallout <0.003%
*Food and water 8% (e.g., potassium)
Medicine and diagnostics 15%
Marie Curie (1867-1934)

Pioneer in magnetism and radioactivity
Winner of two Nobel Prizes
First Woman Professor at Sorbonne
Discovered and named Radium and Polonium

Table 33.1

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Notes: For transuranium elements, the atomic number is the number of protons in the nucleus, while the mass number is the total number of protons and neutrons in the nucleus. The discoverer is listed as the individual who first isolated the element in a pure state. The symbol is the standard chemical symbol for the element. The discovery date is the date when the element was first isolated in a pure state.
Clicker Question:

You find out that you have just received an accidental dose of 250 rems. Should you be concerned?
A: Yes
B: No
C: Only if you were thinking of starting a family

Clicker Question:

Which of the following emits gamma rays whenever it is on?
A: CRT televisions
B: Liquid Crystal Displays (LCDs)
C: Plasma TVs
D: Guns