

Preview of Period 11: Ionizing Radiation II

11.1 How Is Ionizing Radiation Detected?

What do you see in the cloud chamber?

What other methods do we have for detecting ionizing radiation?

11.2 What Natural Sources of Radiation are Present?

Are these sources of radiation harmful?

Can we avoid exposure to them?

11.3 What is Radon?

Why is radon harmful?

11.4 Rates of Radioactive Decay

How can capacitor discharge be used to model radioactive decay?

How can the half-life of a radioactive source be used to find the age of the source?

Ionizing Radiation

Ionizing radiation is radiation that strips electrons from atoms, turning the atoms into charged ions.

- Materials containing atoms with unstable nuclei are **radioactive**.
- As the nuclei decay, they give off ionizing radiation
- The radiation the nuclei give off is some combination of alpha, beta, or gamma particles, depending on the nuclear reaction.

Radiation	Particle emitted	A= # of nucleons	Z= # of protons	Electric Charge
alpha α	helium nuclei ${}^4_2\text{He}$	4	2	+2
beta β^-	electron (e^-)	0	0	-1
beta β^+	antielectron (e^+)	0	0	+1
gamma γ	high energy photon	0	0	0

The Cloud Chamber

- Alcohol vapor in the cloud chamber is cooled by dry ice (frozen carbon dioxide).
- The alcohol temperature is slightly below the temperature at which it would normally condense into droplets. (The vapor is **supercooled**.)
- Ions are produced along the paths of the particles that result from the decay of the radioactive sources.
- These ions seed the **supercooled vapor** and form tiny raindrops around the ions, leaving visible tracks.

The tracks can reveal the **ionization density** of the source, since some tracks appear thicker (more droplets) than others.

Cloud chamber vapor trails that do not come from the radioactive sources are from **cosmic rays** - very high energy protons from space.

Detecting Ionizing Radiation

Ionizing radiation can be detected by:

Film because the energy deposited by ionizing radiation in photographic film causes chemical changes in the film, much as light does.

A **Geiger counter** because an electrical signal is produced each time an ionizing particle passes through the counter tube. The electrical signal is amplified and heard as clicks from a loudspeaker.

A **cloud chamber** produces a visible track along the path of ions left by the passage of an ionizing particle.

Penetrating Ability of Ionizing Radiation

Ionizing radiation particles (**alpha** α , **beta** β , and **gamma** γ) are named in order of increasing penetrating ability.

Comparison of Ionizing Radiation types

Particle	Type	Charge	Ionizing density	Penetrating ability
alpha α	helium nuclei ${}^4_2\text{He}$	+2	highest	lowest
beta β^-	electron (e^-)	-1	moderate	moderate
beta β^+	antielectron (e^+)	+1	moderate	moderate
gamma γ	high energy photon	0	lowest	highest

Exposure to Radiation

Exposure to ionizing radiation depends on the

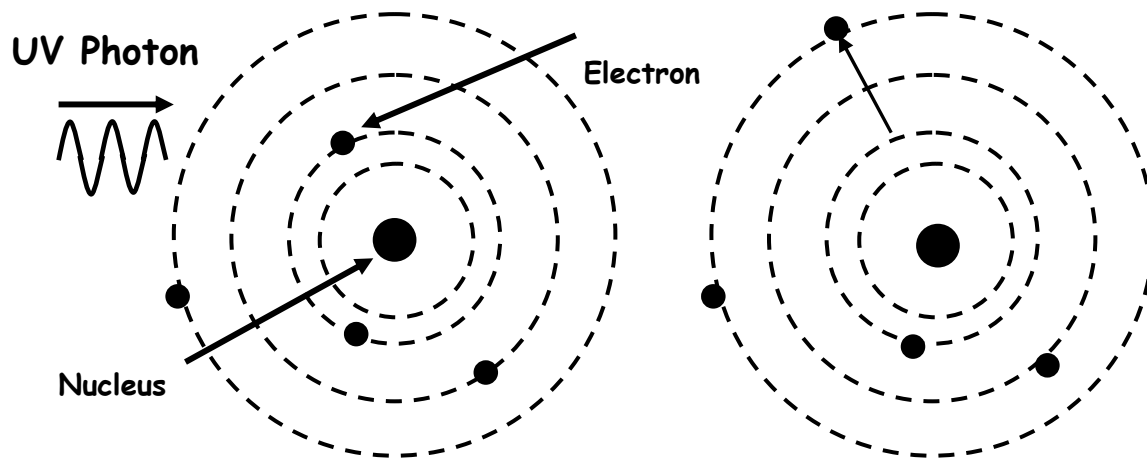
- ◆ number of ionizing particles
- ◆ time exposed to the particles
- ◆ energy of the particles

Exposure per person can vary greatly, but the average person's annual exposure is **200 millirems** (mrem)

What natural sources of radioactivity are we exposed to? Can we avoid these sources?

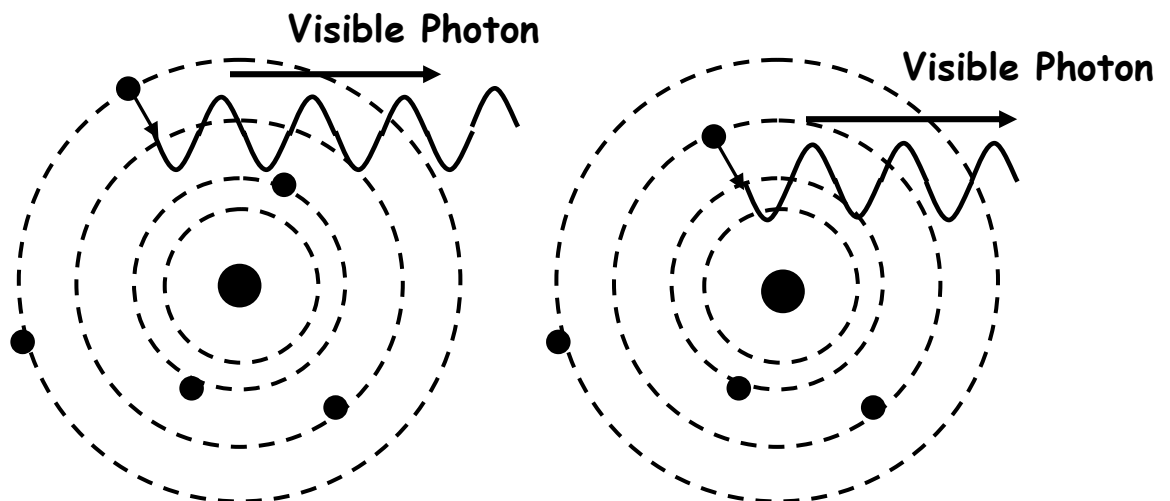
An Atom Fluorescing

Fluorescence is the absorption of radiant energy and the emission of radiant energy at longer wavelengths.



Time 1: An ultraviolet light photon is absorbed by an electron.

Time 2: The electron moves up two energy levels.

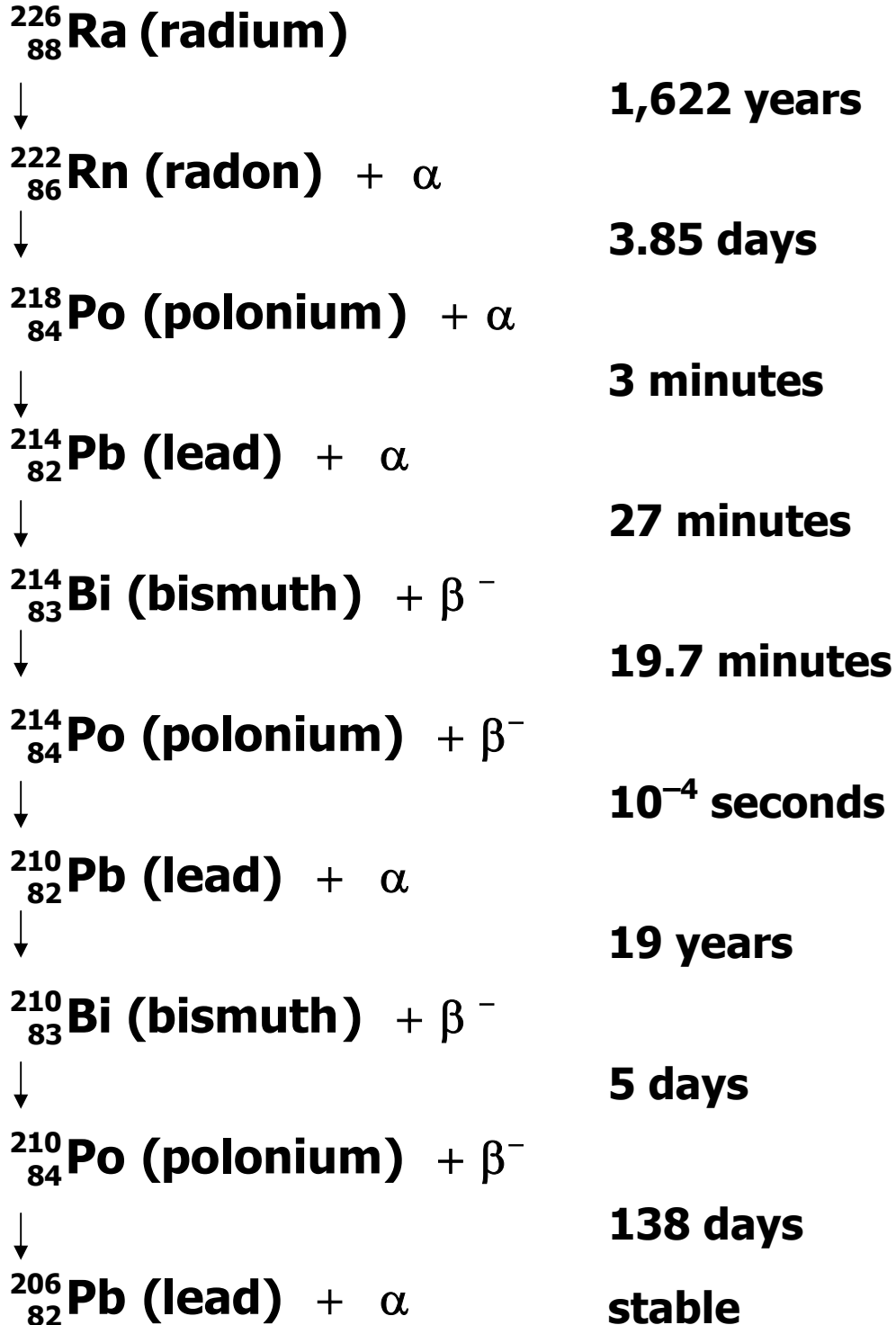


Time 3: The electron drops down one energy level and emits one photon of visible light.

Time 4: The electron drops down one more energy level and emits a second photon.

Decay Products of Radon-222 and their Half Lives

(Shown is the most common chain of decays.)



Half-Life of Radioactive Sources

- ◆ The half-life of a radioactive source is the time required for half of the unstable nuclei to decay.
- ◆ After one half-life, the material will be only half as radioactive.
- ◆ The number of the original nuclei remaining will be only half what it was originally.

Number of Half Lives	Fraction of Original	Number of Half Lives	Fraction of Original
0	$1 = \frac{1}{2^0}$	6	$\frac{1}{64} = \frac{1}{2^6}$
1	$\frac{1}{2} = \frac{1}{2^1}$	7	$\frac{1}{128} = \frac{1}{2^7}$
2	$\frac{1}{4} = \frac{1}{2^2}$	8	$\frac{1}{256} = \frac{1}{2^8}$
3	$\frac{1}{8} = \frac{1}{2^3}$	9	$\frac{1}{512} = \frac{1}{2^9}$
4	$\frac{1}{16} = \frac{1}{2^4}$	10	$\frac{1}{1024} = \frac{1}{2^{10}}$
5	$\frac{1}{32} = \frac{1}{2^5}$		

Finding the Half-Life of a Graph with Background

- 1) Pick a data point on your graph and read the Y-axis value (the voltage in our activity).
- 2) Subtract the background voltage.
- 3) Divide the result in half.
- 4) Add back in the background voltage. This gives $\frac{1}{2}$ the original voltage, corrected for the background.
- 5) Find this voltage on your graph.
- 6) Read down to the X-axis from this point to find a time in seconds.
- 7) The difference in seconds between this time and the time of your original point is the half-life - the time it took for $\frac{1}{2}$ of the capacitor's charge to be released.

Exponential Growth and Decay

exponential growth: $N = B \times 2^a$

exponential decay: $N = B \times 2^{-a} = B \times \frac{1}{2^a}$

N = the amount of the quantity at a given time

a = the number of time periods elapsed

B = the initial amount of the quantity

Example

A sample of radioactive material has a half life of 15 minutes. If there are 5.0 grams of the material at the beginning of an experiment, how much will be left after 1 hour has passed?

After 1 hour, four 15-minute half lives have passed.

$$\begin{aligned} N &= B \times \frac{1}{2^t} \\ &= 5.0 \text{ grams} \times \frac{1}{2^4} = 5.0 \text{ g} \times \frac{1}{16} = 0.31 \text{ g} \end{aligned}$$

Decay of Carbon-14: $^{14}_6\text{C}$

- Carbon-14 decays by emitting a β^- particle and an antineutrino:



- Carbon-14 is produced when cosmic rays convert stable nitrogen-14 in the air into carbon-14.

A β^+ particle and a neutrino are emitted.



Carbon-14 Dating

- ◆ Carbon-14 ($^{14}_6\text{C}$) can be used to date archeological sites.
- ◆ Both stable Carbon-12 and unstable carbon-14 isotopes are present in the atmosphere.
- ◆ Living organisms absorb both isotopes of carbon.
- ◆ After an organism dies, it no longer absorbs any new carbon-14, and the carbon-14 within it decays.
- ◆ We can accurately estimate the time of an organism's death, if we know
 - 1) the ratio of carbon-12 to carbon-14 in the atmosphere at the time the organism died
 - 2) the present ratio of carbon-12 to carbon-14 in the fossil, and
 - 3) the half-life of carbon-14 (5,730 years)

Period 11 Summary

11.1 Ionizing radiation can be detected by Geiger counters, cloud chambers, film badges, and radon detectors.

11.2 Because ionizing radiation can damage living tissue, shielding may be used to block the radiation.

Since gamma particles are the most penetrating, they are more difficult to shield against.

11.3 Health damage from ionizing radiation includes killing cells, genetic damage, and increased risk of cancer.

11.4 Sources of ionizing radiation include radon decay, cosmic rays, medical X-rays, radioactive decay inside your body, and rocks, soil, and building materials.

11.5 The half-life of an unstable element is the time it takes on average for one half of the nuclei in the sample to decay.

Radio-carbon dating uses the half life of Carbon-14 (${}^{14}_6\text{C}$) to determine the age of objects. Carbon-14 has a half life of 5,730 years.

Period 11 Review Questions

- R.1** In class you used capacitor decay to model radioactive decay and graphed the count rate (voltage) per unit time. What was the shape of your graph? Some graphs leveled off at a count rate greater than zero. Why?
- R.2** Carbon-14 dating cannot be used for objects older than about 70,000 years. Why should this be true? (Hint: the half-life of C-14 is 5730 years.)
- R.3** The half life of Ba-137 is about 2.6 minutes. If you took a count rate from the Ba-137 30 minutes (about 12 half lives) after it was extracted, could you estimate this elapsed time well from such counting rate data?
- R.4** How does radon-222 increase the risk of lung cancer? How can radon-222 be detected? What should be done if high levels of radon gas are found in a home?
- R.5** Can you decrease your natural radiation exposure significantly by avoiding foods containing potassium? Should you avoid medical X-rays to reduce your radiation exposure?
- R.6** Why is it so difficult to determine how many cases of cancer are caused by a small increase in a population's radiation exposure?