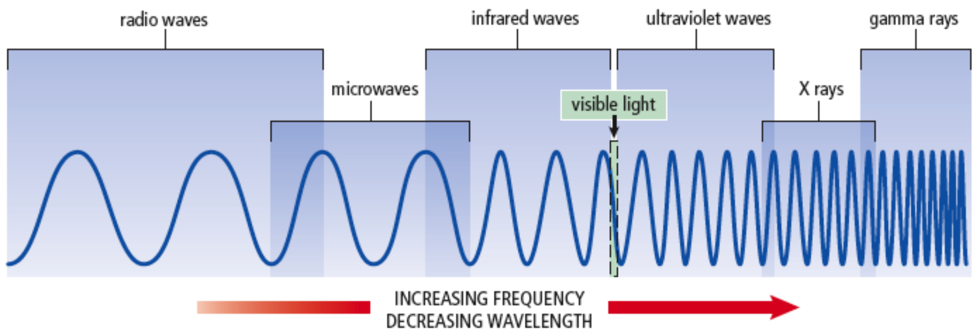
7.1 Atomic Theory and Radioactive Decay

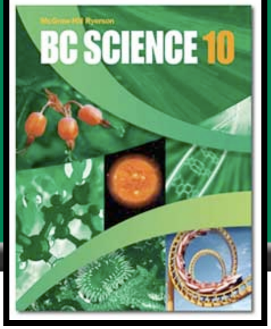
- **Natural background radiation exists all around us.**
  - **This radiation consists of high energy particles or waves being emitted from a variety of materials.**
- **Radioactivity is the release of high-energy particles or waves.**
  - **Being exposed to radioactive materials can be beneficial or harmful.**
    - **X rays, radiation therapy, and electricity generation are beneficial.**
    - **High-energy particles and waves damage DNA in our cells.**
  - **When atoms lose high-energy particles and waves, ions or even new atoms can be formed.**
  - **High-energy waves and particles are called radiation when they leave the atom.**

The electromagnetic epectrum

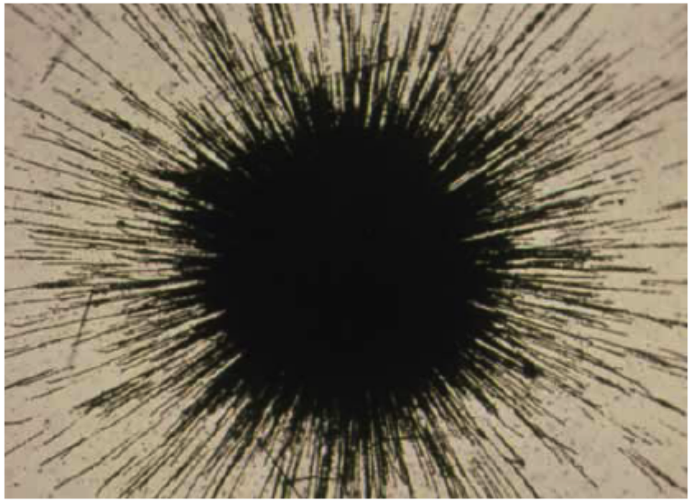


See pages 286 - 287

Searching for Invisible Rays



- **Radiation is everywhere, but can be difficult to detect.**
  - **Roentgen named X rays with an "X" 100 years ago because they were previously unknown.**
  - **Becquerel realized uranium emitted seemingly invisible energy as well.**
  - **Marie Curie and her husband Pierre named this energy radioactivity.**
    - **Early discoveries of radiation relied on photographic equipment.**
  - **Later, more sophisticated devices such as the Geiger-Müller counter were developed to more precisely measure radioactivity.**



Radium salts, after being placed on a photographic plate, leave behind the dark traces of radiation.

See pages 288 - 289

Isotopes and Mass Number

- **Isotopes are different atoms of the same element, with different numbers of neutrons in the nucleus.**
  - **Isotopes have the same number of protons and therefore the same atomic number as each other.**
  - **By having different numbers of neutrons, isotopes have different mass numbers.**
    - **Isotopes of an element have the same symbol and same atomic number**
    - **Mass number refers to the protons + neutrons in an isotope**
    - **Atomic mass = proportional average of the mass numbers for all isotopes of an element.**
      - **19.9% of boron atoms have 5 neutrons, 80.1% have 6 neutrons**
      - **19.9% have a mass number of 10, and 80.1% have a mass number of 11**
      - **(.199 * 10) + (.801*11) = 10.8 = atomic mass of boron**

5
B
Boron
10.8

See page 289 - 290

Representing Isotopes

- Isotopes are written using standard atomic notation.
  - Chemical symbol + atomic number + mass number.
  - Potassium has three isotopes, $^{39}_{19}K$, $^{40}_{19}K$, $^{41}_{19}K$

19 +
K
Potassium
39.1

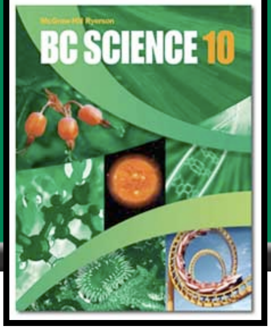
Table 7.1 Isotopes of Potassium

	Potassium-39	Potassium-40	Potassium-41
Protons (nucleus)	19	19	19
Neutrons (nucleus)	20	21	22
Electrons (in shells)	19	19	19

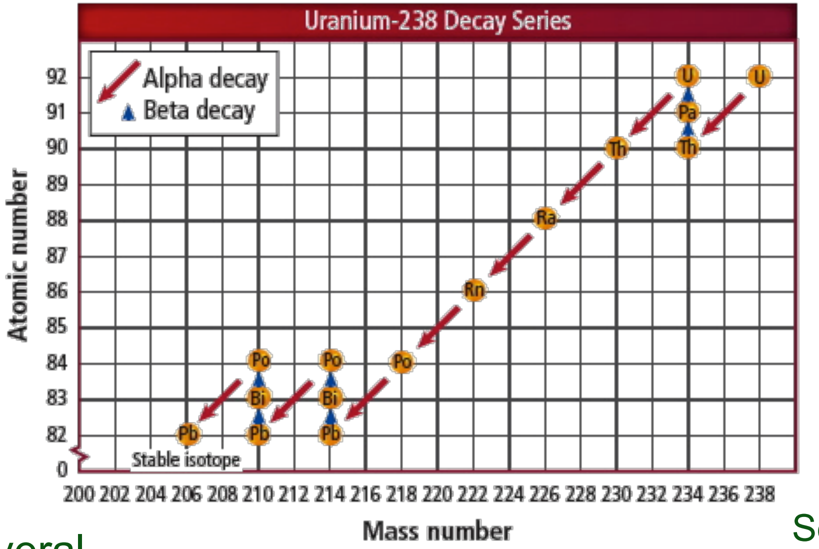
- Potassium is found in nature in a certain ratio of isotopes.
  - 93.2% is potassium-39, 0.1% is potassium-40, and 6.7% is potassium-41
  - Atomic mass = (0.932 x 39) + (0.001 x 40) + (0.067 x 41) = 39.1

See page 290

Radioactive Decay



- Unlike all previously discovered chemical reactions, radioactivity sometimes results in the formation of completely new atoms.
  - Radioactivity results from having an unstable nucleus.
  - When these nuclei lose energy and break apart, decay occurs.
    - Radioactive decay releases energy from the nucleus as radiation.
    - Radioactive atoms release energy until they become stable, often as different atoms.
    - An element may have only certain isotopes that are radioactive.
      - These are called <u>radioisotopes</u>.



Radioisotope uranium-238 decays in several stages until it finally becomes lead-206.

See page 293

Three Types of Radiation

- Rutherford identified three types of radiation using an electric field.
  - Positive alpha particles were attracted to the negative plate.
  - Negative beta particles were attracted to the positive plate.
  - Neutral gamma rays did not move towards any plate.

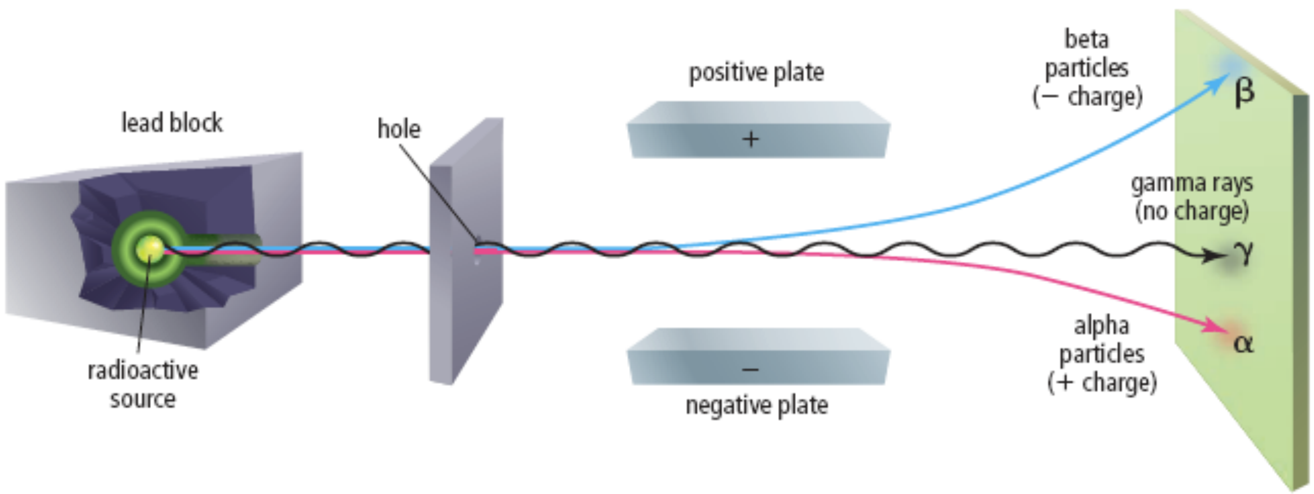
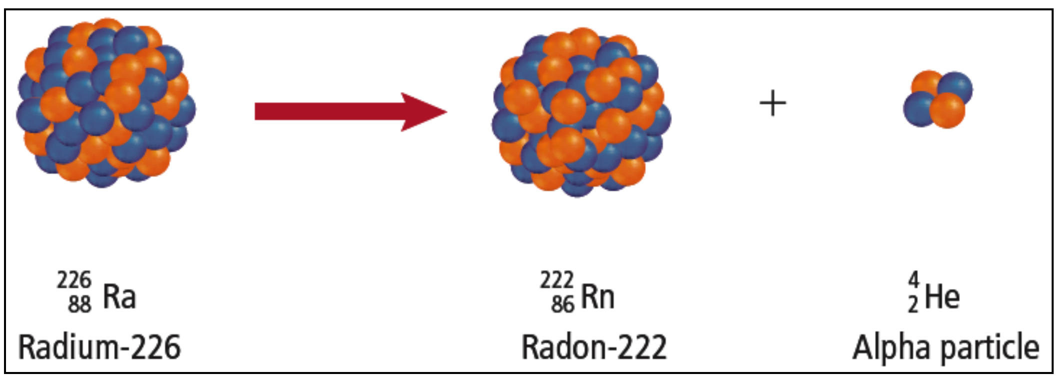


Figure 7.9 Alpha particles are deflected toward the negative plate. Beta particles are deflected toward the positive plate. Gamma radiation is not deflected by the electric field.

See page 294

Three Types of Radiation (continued) : Alpha Radiation

- **Alpha radiation is a stream of alpha particles.**
  - **They are positively charged, and are the most massive of the radiation types.**
  - **Alpha particles are essentially the same as helium atoms.**
  - **Alpha particles are represented by the symbols $^{4}_{2}\alpha$ or $^{4}_{2}\mathrm{He}$.**
    - **Because it has two protons, it has a charge of 2+.**
    - **The release of alpha particles is called alpha decay.**
  - **Alpha particles are slow and penetrate materials much less than the other forms of radiation. A sheet of paper will stop an alpha particle.**



$$^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{88}\mathrm{Rn} + {}^{4}_{2}\alpha$$

or

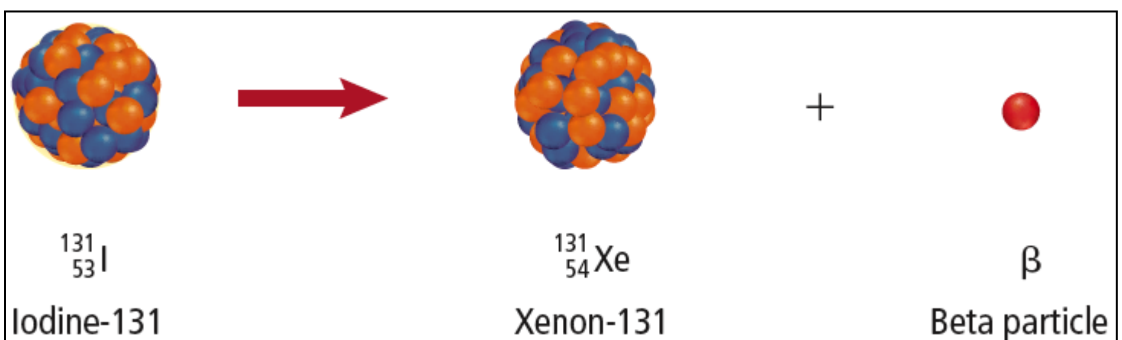
$$^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{88}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$$

Radium-226 releases an alpha particle and becomes Radon-222. Radon has two less protons than radium.

See page 294 - 295

Three Types of Radiation (continued) : Beta Radiation

- A beta particle is an electron and is negatively charged.
  - Beta particles are represented by the symbols $^{0}_{-1}\beta$ or $^{0}_{-1}e$.
    - Electrons are very tiny, so beta particles are assigned a mass of 0.
    - Since there is only an electron, a beta particle has a charge of 1–.
  - Beta decay occurs when a neutron changes into a proton and an electron.
    - The proton stays in the nucleus, and the electron is released.
    - It takes a thin sheet of aluminum foil to stop a beta particle.



$$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\beta$$

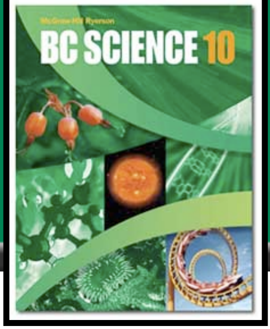
or

$$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}e$$

Iodine-131 releases a beta particle and becomes xenon-131. A neutron has turned into a proton and the released electron.

See page 296

Three Types of Radiation (continued) : Gamma Radiation



- **Gamma radiation is a ray of high-energy, short-wavelength radiation.**
  - **Gamma radiation has no charge and no mass, and is represented by the symbol $^{0}_{0}\gamma$**
  - **Gamma radiation is the highest-energy form of electromagnetic radiation.**
    - **It takes thick blocks of lead or concrete to stop gamma rays.**
  - **Gamma decay results from energy being released from a high-energy nucleus.**

$$^{60}_{28}\text{Ni}^{*} \rightarrow \, ^{60}_{28}\text{Ni} + \, ^{0}_{0}\gamma$$

  - **Often, other kinds of radioactive decay will also release gamma radiation.**
    - **Uranium-238 decays into an alpha particle and also releases gamma rays.**

$$^{238}_{92}\text{U} \rightarrow \, ^{234}_{90}\text{Th} + \, ^{4}_{2}\text{He} + 2\gamma$$

See page 297

Radiation and Radioactive Decay Summaries, and Nuclear Equations for Radioactive Decay

Table 7.3 Properties of Alpha, Beta, and Gamma Radiation

Property	Alpha Radiation	Beta Radiation	Gamma Radiation
Symbol	$^{4}_{2}\alpha$ or $^{4}_{2}He$	$^{0}_{-1}\beta$ or $^{0}_{-1}e$	$^{0}_{0}\gamma$
Composition	Alpha particles	Beta particles	High-energy electromagnetic radiation
Description of radiation	Helium nuclei, $^{4}_{2}He$	Electrons	High energy rays
Charge	2+	1−	0
Relative penetrating power	Blocked by paper	Blocked by metal foil or concrete	Partly or completely blocked by lead

Table 7.4 Summary of Radioactive Decay Processes

	Alpha Decay	Beta Decay	Gamma Decay
Particle emitted	$^{4}_{2}\alpha$ or $^{4}_{2}He$	$^{0}_{-1}\beta$ or $^{0}_{-1}e$	$^{0}_{0}\gamma$
Change in mass number of starting nucleus	Decreases by 4	No change	No change
Change in atomic number of starting nucleus	Decreases by 2	Increases by 1	No change

Nuclear equations are written like chemical equations, but represent changes in the nucleus of atoms.

- Chemical equations represent changes in the position of atoms, not changes to the atoms themselves.

1. The sum of the mass numbers does not change.
2. The sum of the charges in the nucleus does not change.

See pages 298 - 299

Take the Section 7.1 Quiz