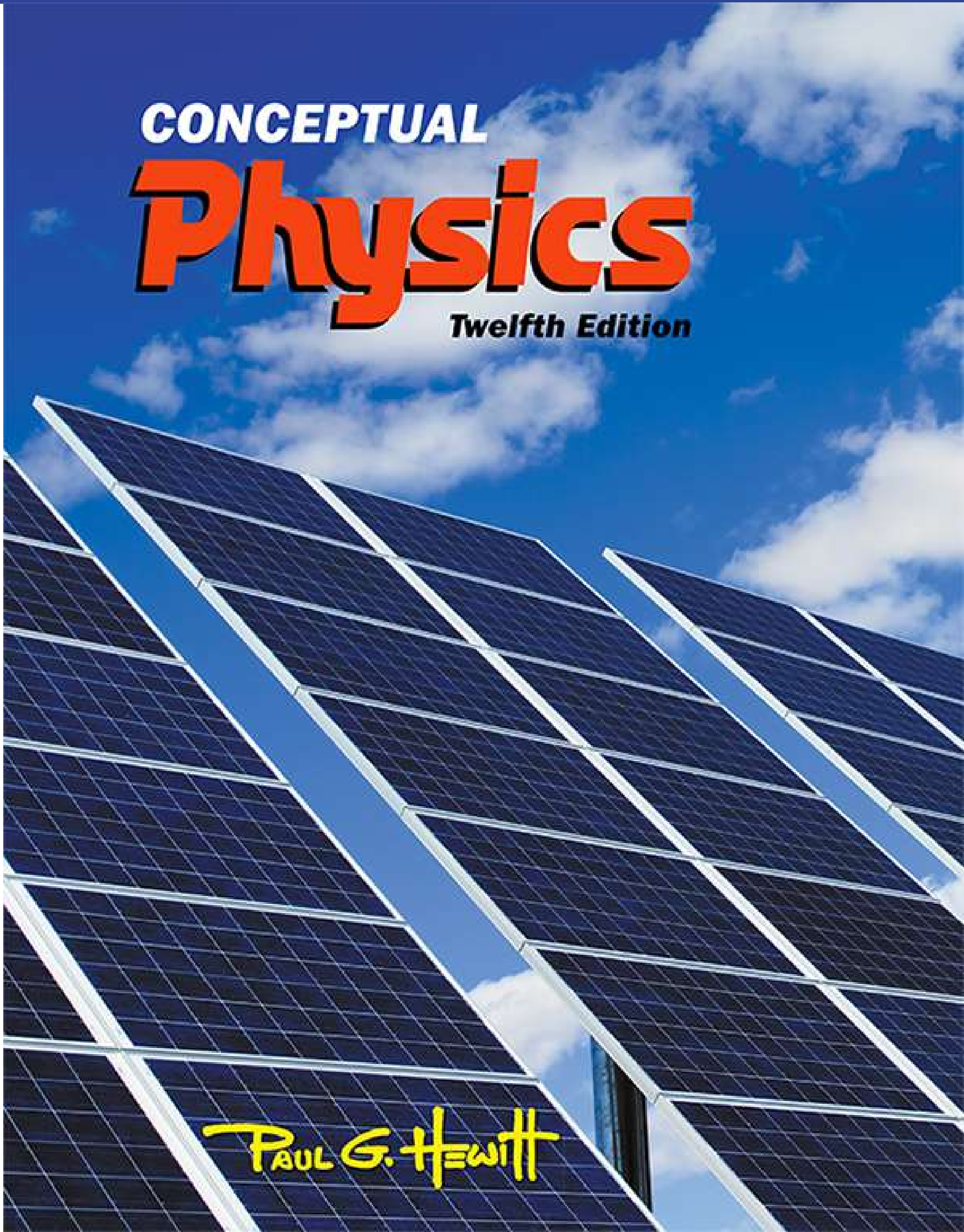
Chapter 33: The Atomic Nucleus and Radioactivity and Chapter 11: Isotopes

Part 1



© 2015 Pearson Education, Inc.

Roentgen and the first x-ray:

Roentgen:

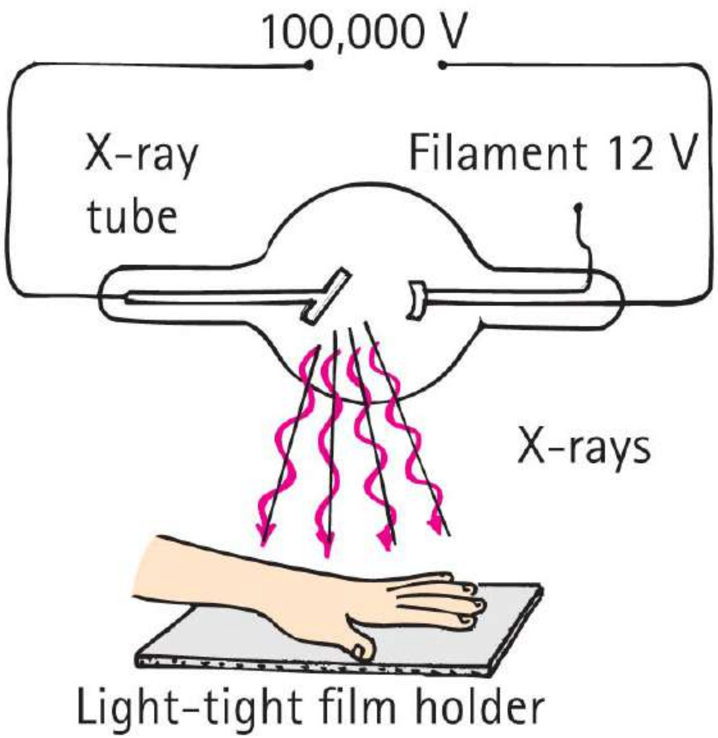
His wife's hand:

"I have seen my death!"

© 2015 Pearson Education, Inc.

X-Rays and Radioactivity

- Roentgen discovered X-rays produced by a beam of electrons striking the glass surface of a gas-discharge tube.
- He found that X-rays could pass through solid materials, could ionize the air, showed no refraction in glass, and were undeflected by magnetic fields.



© 2015 Pearson Education, Inc.

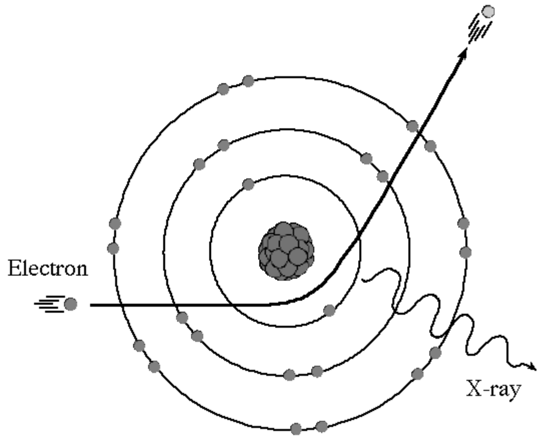
Classwork

1. What did Roentgen discover about a cathode-ray beam striking a glass surface?

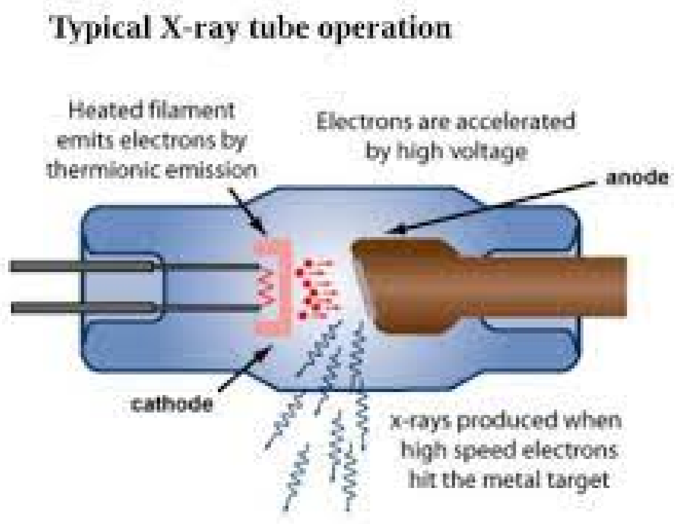
© 2015 Pearson Education, Inc.

X-Rays and Radioactivity, Continued

X-rays are high-frequency electromagnetic waves, usually emitted by the de-excitation of the innermost orbital electrons of atoms.



An energetic beam of electrons striking a solid surface excites the innermost electrons and produces higher-frequency photons of X-radiation (dentist x-rays).



© 2015 Pearson Education, Inc.

X-Rays and Radioactivity, Continued-1

- X-ray photons have high energy and can penetrate many layers of atoms before being absorbed or scattered.

- X-rays do this when they pass through your soft tissue to produce an image of the bones inside your body.

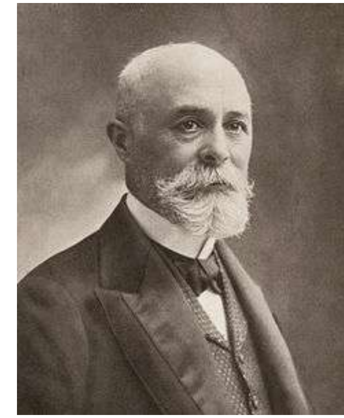
© 2015 Pearson Education, Inc.

Classwork:

2. What kind of rays are X-rays?

© 2015 Pearson Education, Inc.

Henri Becquerel (French)



Discovered evidence of radioactivity (he and the Curies received a Nobel Prize together in 1903)

He thought the uranium rocks had to be exposed to the Sun before they would make an image on a photographic plate. One rainy day, he put the rock in a drawer next to a photographic plate. The next day, he developed the plate anyway and saw an image made by the rock.

→ The rocks were “active” without the sun!

© 2015 Pearson Education, Inc.

Classwork:

3. What did the Becquerel discover about uranium?

© 2015 Pearson Education, Inc.

Marie Curie

Winner of 2 Nobel Prizes:

in *Chemistry* and *Physics*

(only person to win 2 in science)

Processed tons of rocks by hand.

Discovered and named 2 elements:

Polonium and Radium

First female professor at the Sorbonne (University of Paris)

Daughter Irene also won the Nobel Prize in Chemistry.

Died from radiation poisoning.

© 2015 Pearson Education, Inc.

Classwork:

4. What two elements did Pierre and Marie Curie discover?

© 2015 Pearson Education, Inc.

- **Radioactivity**
  - Radioactivity is the process of nuclear decay (radioactive decay).
  - → When a nucleus is **unstable**, it “decays” and emits particles.
  - Nothing new in the environment.
  - It warms Earth's interior, is in the air we breathe, and is present in all rocks (some in trace amounts).
  - It is natural and has been around since Earth formed.
  - Humans have added a small amount.

© 2015 Pearson Education, Inc.

X-Rays and Radioactivity
CHECK YOUR NEIGHBOR

The radioactive decay of nature's elements occurs in the

A. soil we walk on.
B. air we breathe.
C. interior of Earth.
D. All of the above.

© 2015 Pearson Education, Inc.

X-Rays and Radioactivity
CHECK YOUR ANSWER

The radioactive decay of nature's elements occurs in the

D. **All of the above.**

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR NEIGHBOR

The origins of radioactivity go back to

A. military activities in the mid-20th century.
B. the Industrial Revolution two centuries ago.
C. the beginning of human error.
D. before humans emerged on Earth.

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR ANSWER

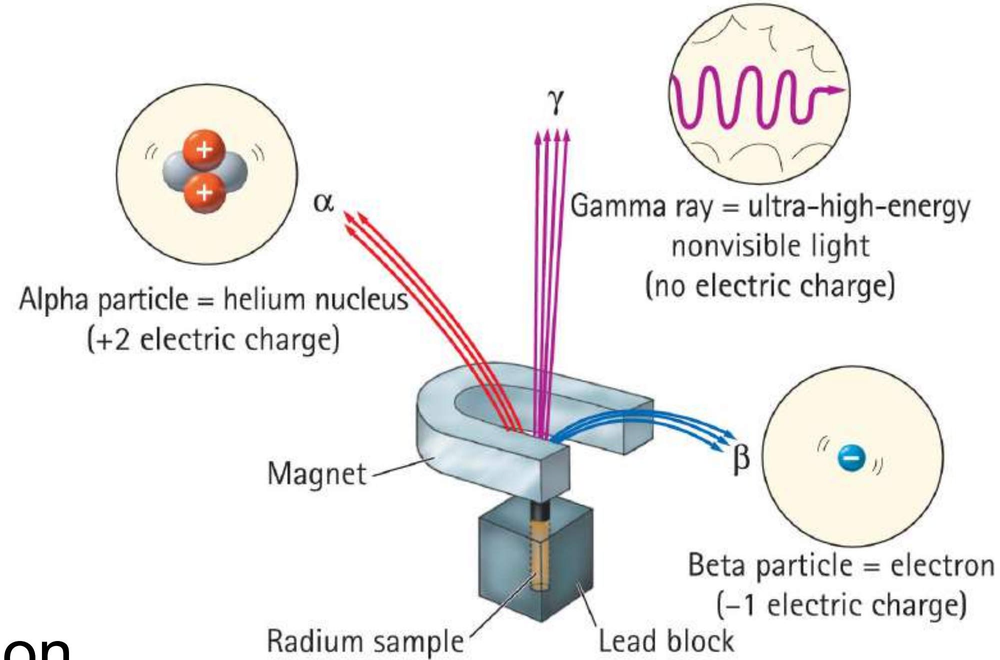
The origins of radioactivity go back to

D. before humans emerged on Earth.

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays

- Radioactive elements emit three distinct types of radiation:
  - α —alpha: positively charged (helium nuclei)
  - β —beta: negatively charged (electrons)
  - γ —gamma:
  - electromagnetic radiation
  - not charged, so they are not bent by a magnetic field



© 2015 Pearson Education, Inc.

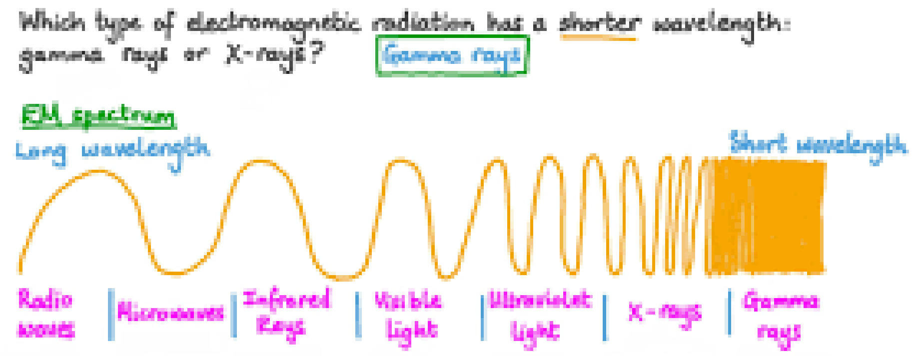
Classwork

5. Why aren't gamma rays deflected in a magnetic field?

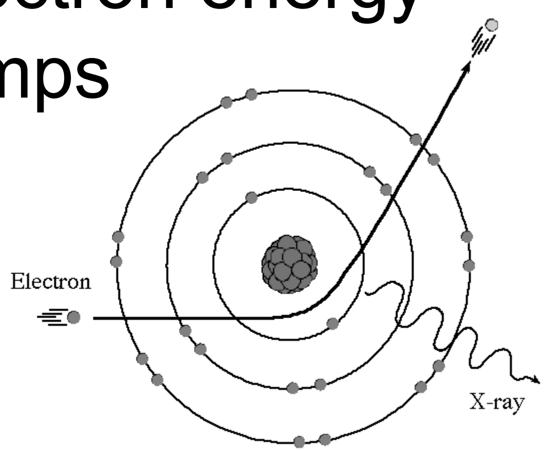
© 2015 Pearson Education, Inc.

Gamma rays have more energy than x-rays.

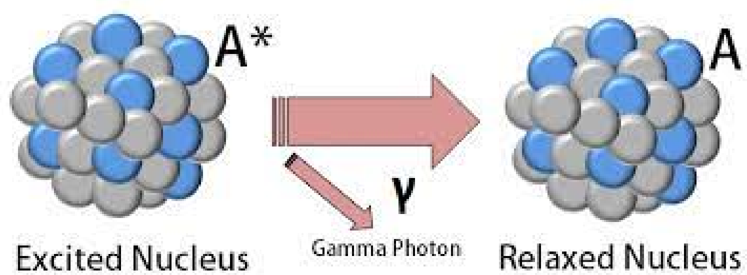
Why?



x-rays: from electron energy jumps



γ-rays: from nucleon energy jumps



Bigger energy jumps
→ higher photon energy
→ E = hf → higher frequency

© 2015 Pearson Education, Inc.

Classwork

6. Which has the higher frequency: X-rays or gamma rays?

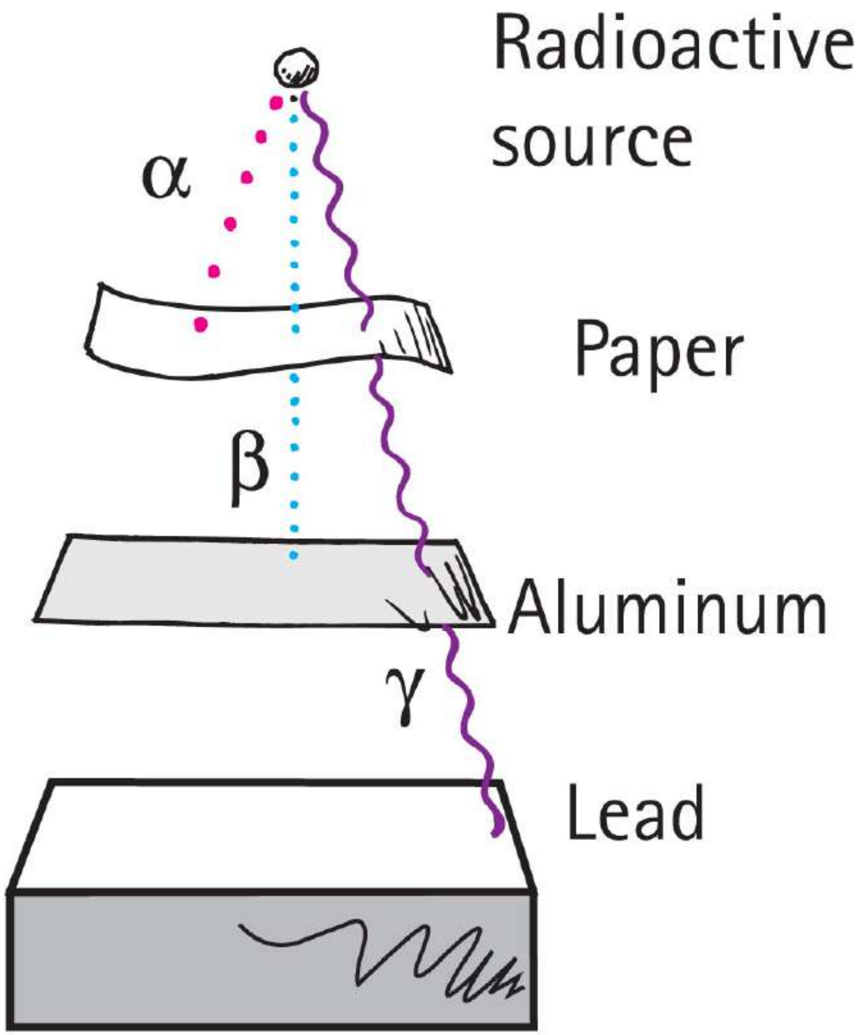
© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays, Continued

- Relative penetrations:

α: easiest to stop

γ: hardest to stop



© 2015 Pearson Education, Inc.

CHECK POINT

Pretend you are given three radioactive rocks—one an alpha emitter, one a beta emitter, and one a gamma emitter. You can throw away one, but of the remaining two, you must hold one in your hand and the other you must place in your pocket. What can you do to minimize your exposure to radiation?

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR NEIGHBOR, Continued

Any atom that emits an alpha particle or beta particle

A. becomes an atom of a different element, always.
B. may become an atom of a different element.
C. becomes a different isotope of the same element.
D. increases its mass.

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR ANSWER, Continued

Any atom that emits an alpha particle or beta particle

A. **becomes an atom of a different element, always.**

Explanation:

Contrary to the failures of alchemists of old to change elements from one to another, this was going on all around them—unnoticed.

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR NEIGHBOR, Continued-1

Which of these is the nucleus of the helium atom?

A. Alpha
B. Beta
C. Gamma
D. All are different forms of helium.

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR ANSWER, Continued-1

Which of these is the nucleus of the helium atom?

A. **Alpha**

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR NEIGHBOR, Continued-2

Which of these is actually a high-speed electron?

A. Alpha
B. Beta
C. Gamma
D. All are high speed.

© 2015 Pearson Education, Inc.

Alpha, Beta, and Gamma Rays
CHECK YOUR ANSWER, Continued-2

Which of these is actually a high-speed electron?

B. **Beta**

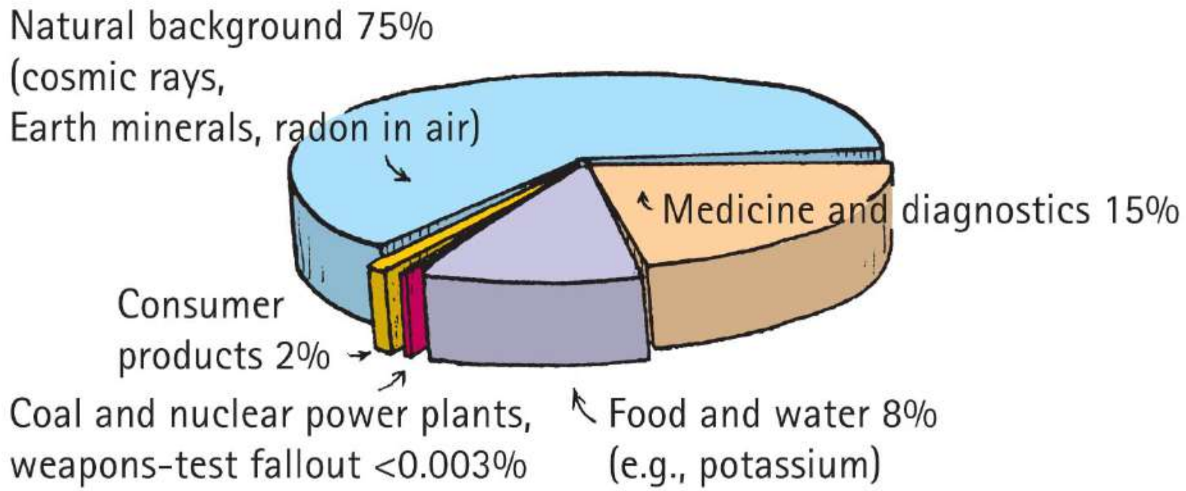
Explanation:

Choice D may be true, but doesn't directly answer the question.

© 2015 Pearson Education, Inc.

Environmental Radiation

– Most radiation from natural background
– About 1/5 from nonnatural sources



The combustion of coal releases about 13,000 tons of radioactive thorium and uranium into the atmosphere each year. The nuke power industry generates 10,000 tons of radioactive waster per year.

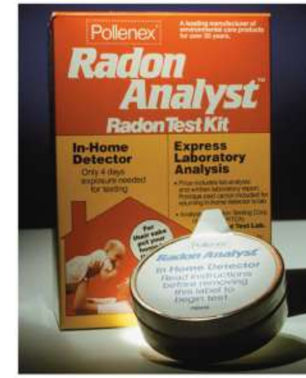
© 2015 Pearson Education, Inc.

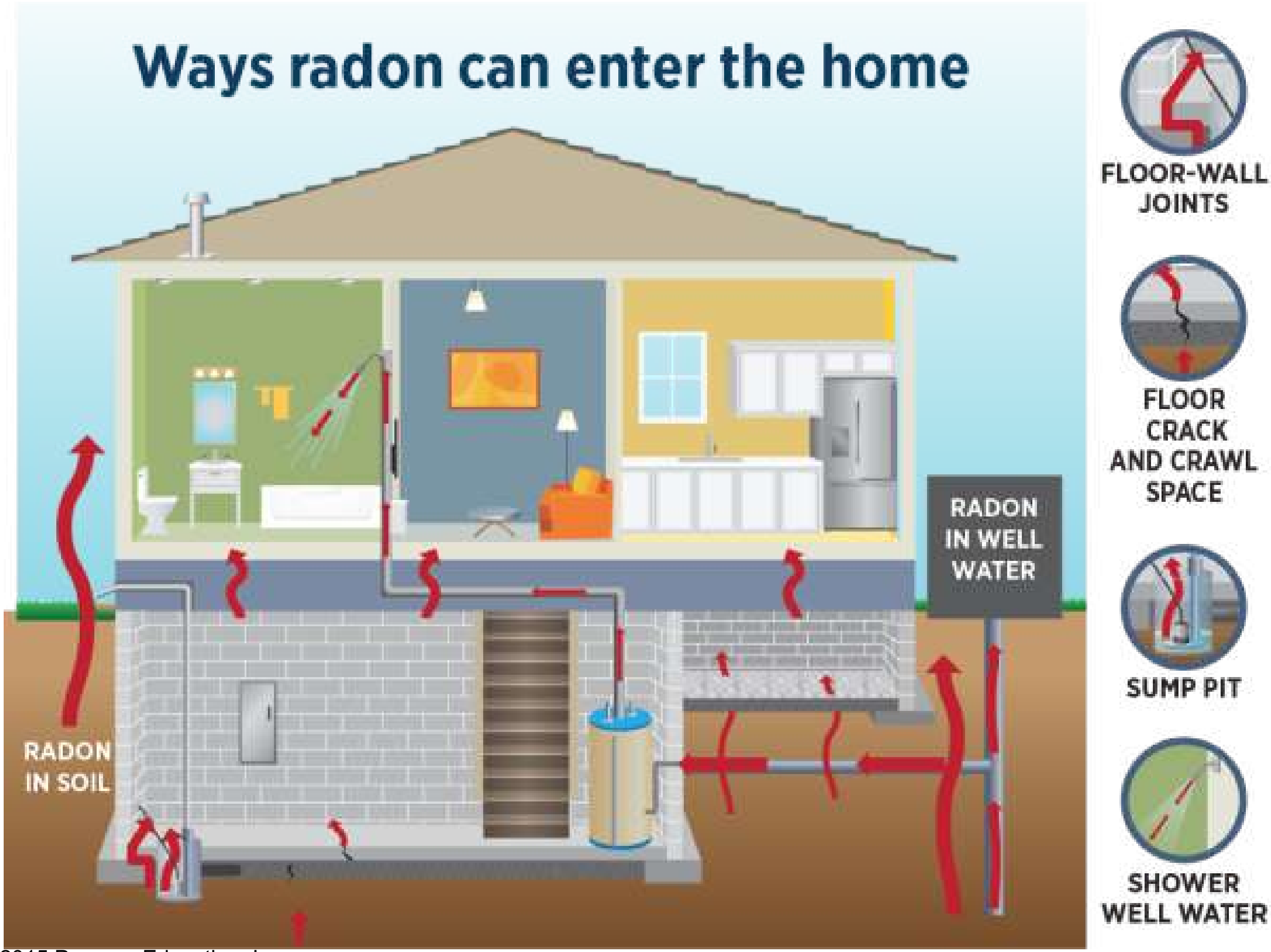
Classwork

8. Do humans receive more radiation from artificial or from natural sources of radiation?

© 2015 Pearson Education, Inc.

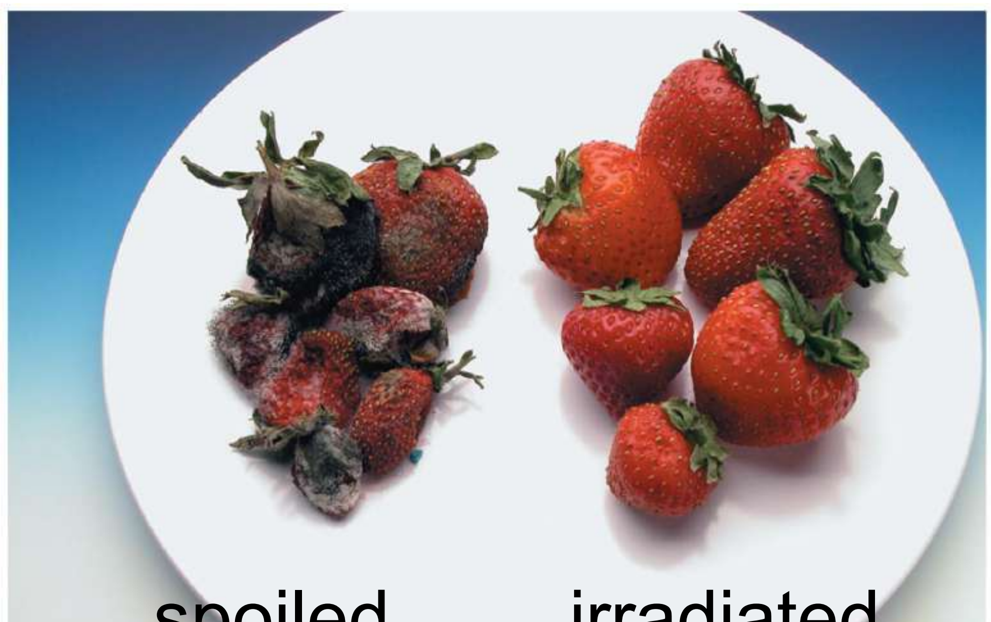
- Radon, a common environmental hazard





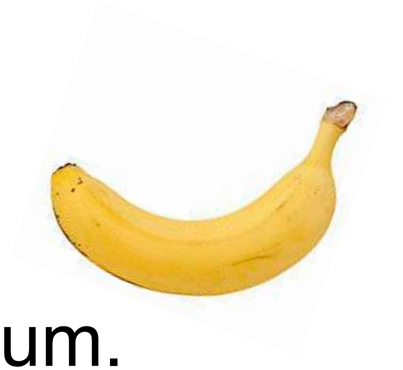
© 2015 Pearson Education, Inc.

- Food irradiation kills microbes.
  γ rays, x-rays and electron beams are used.
  - Doesn't make the food radioactive.
  - Helps prevent spoilage.



© 2015 Pearson Education, Inc.

Your body is radioactive



Bananas contain potassium.

Your body contains some radioactive potassium.

Between every heartbeat, about 60,000 of these decay, giving off gamma rays.

Some carbon in the food you eat is radioactive.

If radiation damages the DNA of a cell, it can cause a mutation.

These mutations can cause cancer.

They can also be passed on to your offspring.

© 2015 Pearson Education, Inc.

Classwork

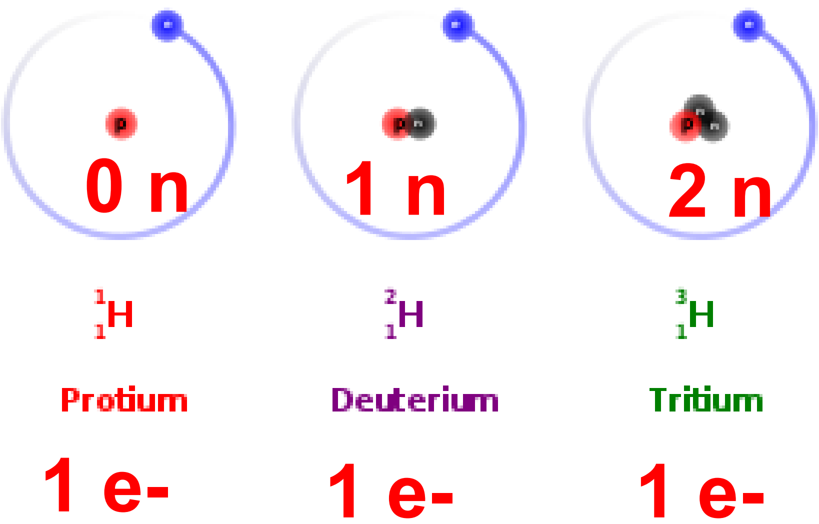
9. Is the human body radioactive? Explain.

© 2015 Pearson Education, Inc.

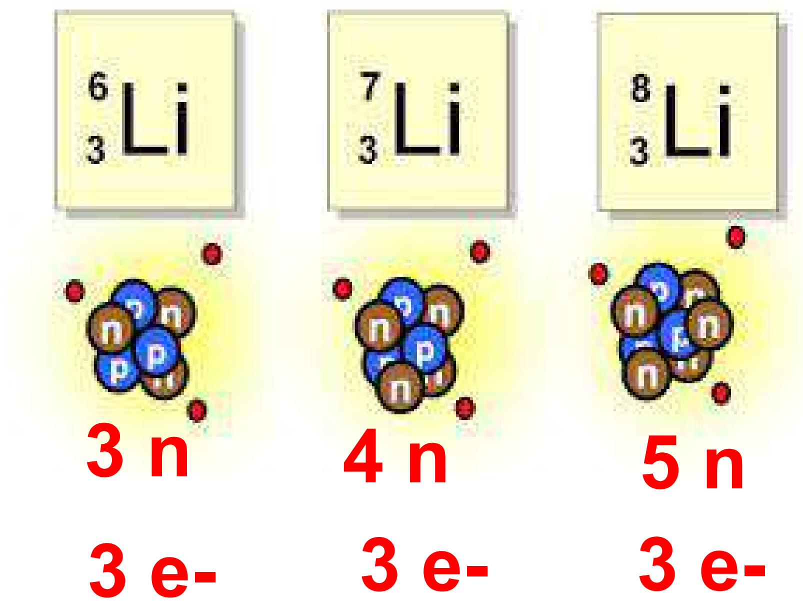
Isotopes:

- Atoms of the same element (same number of protons p) with different numbers of neutrons n
- Identical chemical behavior

Isotopes of hydrogen all have 1 proton:



Isotopes of lithium all have 3 protons:



© 2015 Pearson Education, Inc.

→Protons p in nucleus equals electrons e^- around nucleus, but not necessarily neutrons n.

→An isotope is identified by its *mass number* (total number of protons and neutrons in the nucleus or number of nucleons)

Example:

The iron isotope with 26 p and 30 n has a mass number 56, referred to as iron-56.

→ The atomic number of iron is **always 26** = # p

→ A neutral atom of iron-56 has 26 p and 26 e^-.

→ The atomic number = # of p

= # of e^- in a neutral atom.

© 2015 Pearson Education, Inc.

Isotopes
CHECK YOUR NEIGHBOR

The atomic number of an element matches the number of

A. protons in the nucleus of an atom.
B. electrons in a neutral atom.
C. Both of the above.
D. None of the above.

© 2015 Pearson Education, Inc.

Isotopes
CHECK YOUR ANSWER

The atomic number of an element matches the number of

C. **Both of the above.**

Comment:

When the atomic number doesn't match the number of electrons, the atom is an ion.

© 2015 Pearson Education, Inc.

Isotopes
CHECK YOUR NEIGHBOR, Continued

A nucleus with an atomic number of 44 and a mass number of 100 must have

A. 44 neutrons.
B. 56 neutrons.
C. 100 neutrons.
D. All of the above.

© 2015 Pearson Education, Inc.

Isotopes
CHECK YOUR ANSWER, Continued

A nucleus with an atomic number of 44 and a mass number of 100 must have

B. **56 neutrons.**

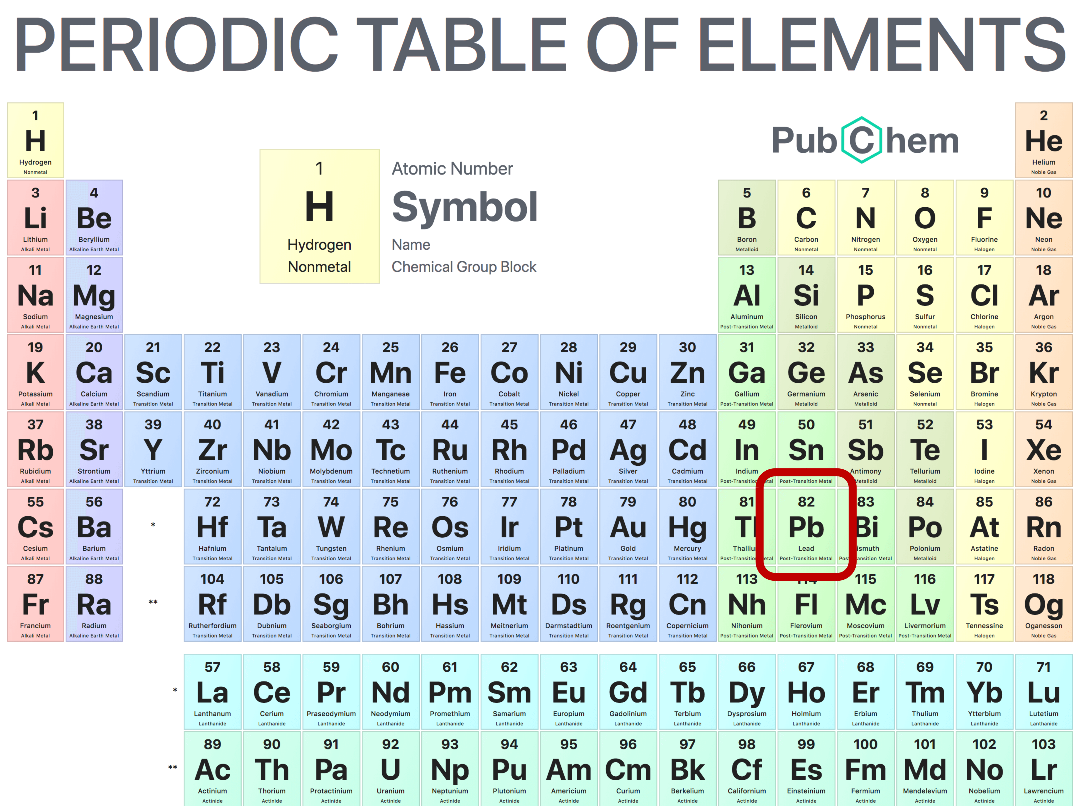
Comment:

Be sure to distinguish between *neutron* and *nucleon*. Of the 100 nucleons in the nucleus, 56 are neutrons. A neutron *is* a nucleon, as is a proton.

© 2015 Pearson Education, Inc.

Periodic Table

99.9% of everyday atoms are stable—not radioactive.
→All elements with an atomic number greater than 82 (lead, Pb) are radioactive.



Pb = lead

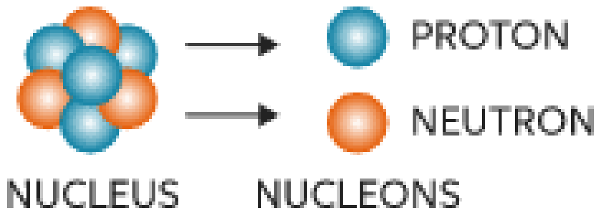
© 2015 Pearson Education, Inc.

Why are some atoms radioactive?

Some isotopes are radioactive. Others are not.

Why?

Look inside nucleus:



The nucleus contains *nucleons*:

protons and neutrons

There are 2 forces that act on nucleons:

1. **Strong force of attraction** between all nucleons

→ All protons and neutrons attract each other.

2. **Electric force of repulsion** between protons.

→ Neutrons are not repelled by this force.

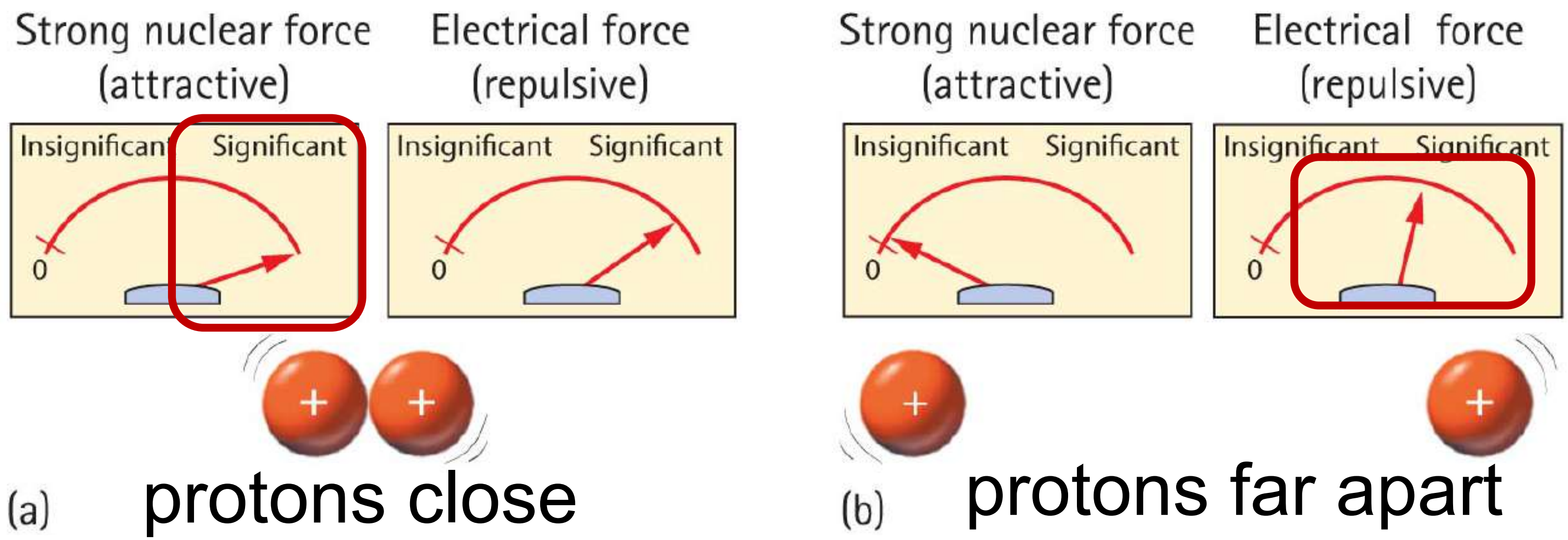
© 2015 Pearson Education, Inc.

Classwork

11. Name the two different nucleons.

© 2015 Pearson Education, Inc.

- The strong force is an attractive force.
- It holds nucleons together.
- It is short range→ weak if nucleons are far apart
- Electric repulsion force is long-range

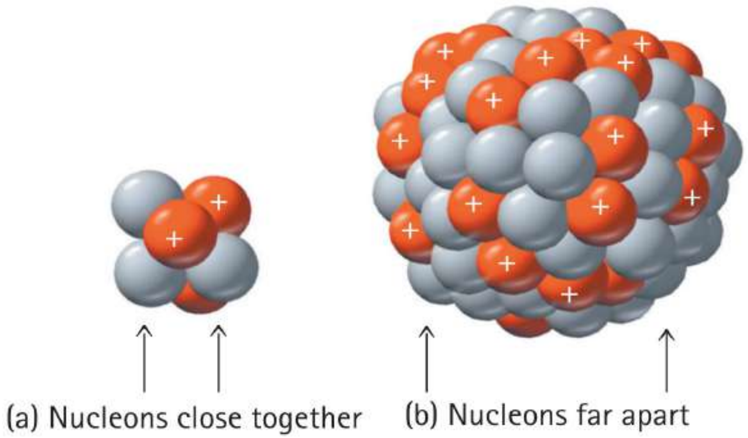


protons close
strong force wins
stable nucleus

protons far apart
electric force wins
unstable nucleus

© 2015 Pearson Education, Inc.

- The strong force is more effective with smaller nuclei.
- In big nuclei, *the protons are too far apart* for the strong force to bind them well.



- Neutrons are the glue that binds the nucleus.
- Neutrons have the strong-force attraction without the electrical repulsion.
- The bigger the nucleus, the more neutrons are needed to hold it together.
- Beyond Pb, the extra neutrons cannot hold it together—the nucleus decays (radioactivity).

© 2015 Pearson Education, Inc.

Classwork

12. Why doesn't the repulsive electrical force of protons in the atomic nucleus cause the protons to fly apart?

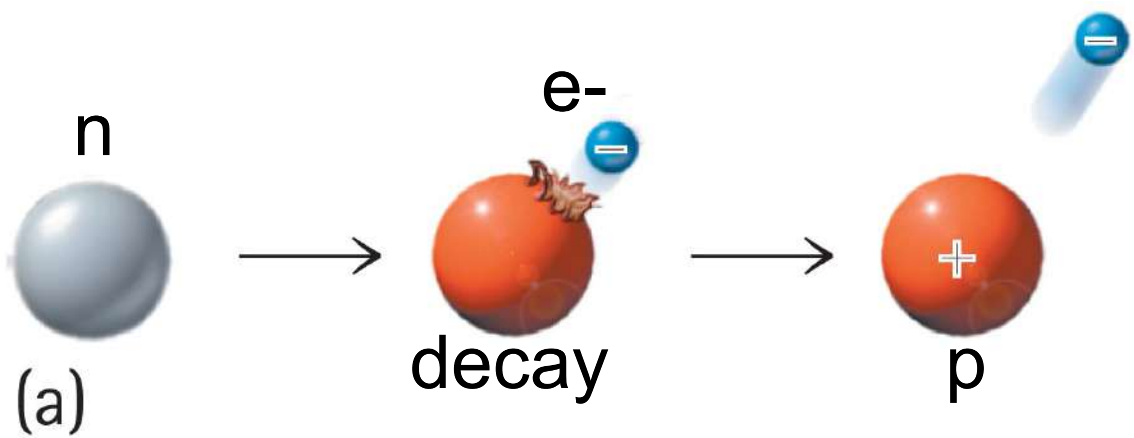
13. Why is a larger nucleus generally less stable than a smaller nucleus?

14. What is the role of neutrons in the atomic nucleus?

15. Which contains the higher percentage of neutrons: large nuclei or small nuclei?

© 2015 Pearson Education, Inc.

- A lone neutron n is radioactive and spontaneously transforms to a proton p and an electron e-.



β decay

This can be written as an equation:

n → p + e-

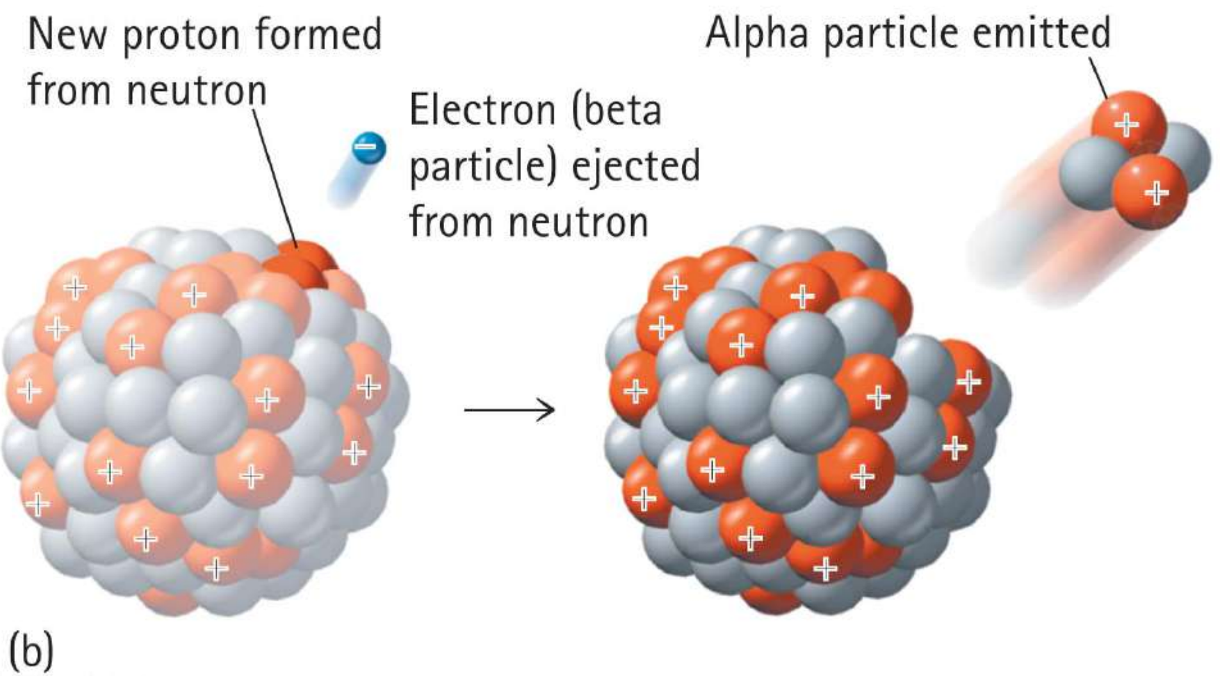
The arrow → means "decays into"

  – A neutron needs protons around to keep this from happening.

© 2015 Pearson Education, Inc.

Too many protons:

- If a neutron in a nucleus decays by emitting an electron, there is an extra proton in the nucleus.
- This makes it unstable, so it emits an α particle:



© 2015 Pearson Education, Inc.

The Atomic Nucleus and the Strong Force
CHECK YOUR NEIGHBOR

The strong force is a force in the

A. atom that holds electrons in orbit.
B. nucleus that holds nucleons together.
C. Both A and B.
D. Neither A nor B.

© 2015 Pearson Education, Inc.

The Atomic Nucleus and the Strong Force
CHECK YOUR ANSWER

The strong force is a force in the

B. **nucleus that holds nucleons together.**

© 2015 Pearson Education, Inc.

The Atomic Nucleus and the Strong Force CHECK YOUR NEIGHBOR, Continued

In the nucleus of an atom, the strong force is a relatively

A. short-range force.
B. long-range force.
C. unstable force.
D. neutralizing force.

© 2015 Pearson Education, Inc.

The Atomic Nucleus and the Strong Force CHECK YOUR ANSWER, Continued

In the nucleus of an atom, the strong force is a relatively

A. **short-range force.**

© 2015 Pearson Education, Inc.