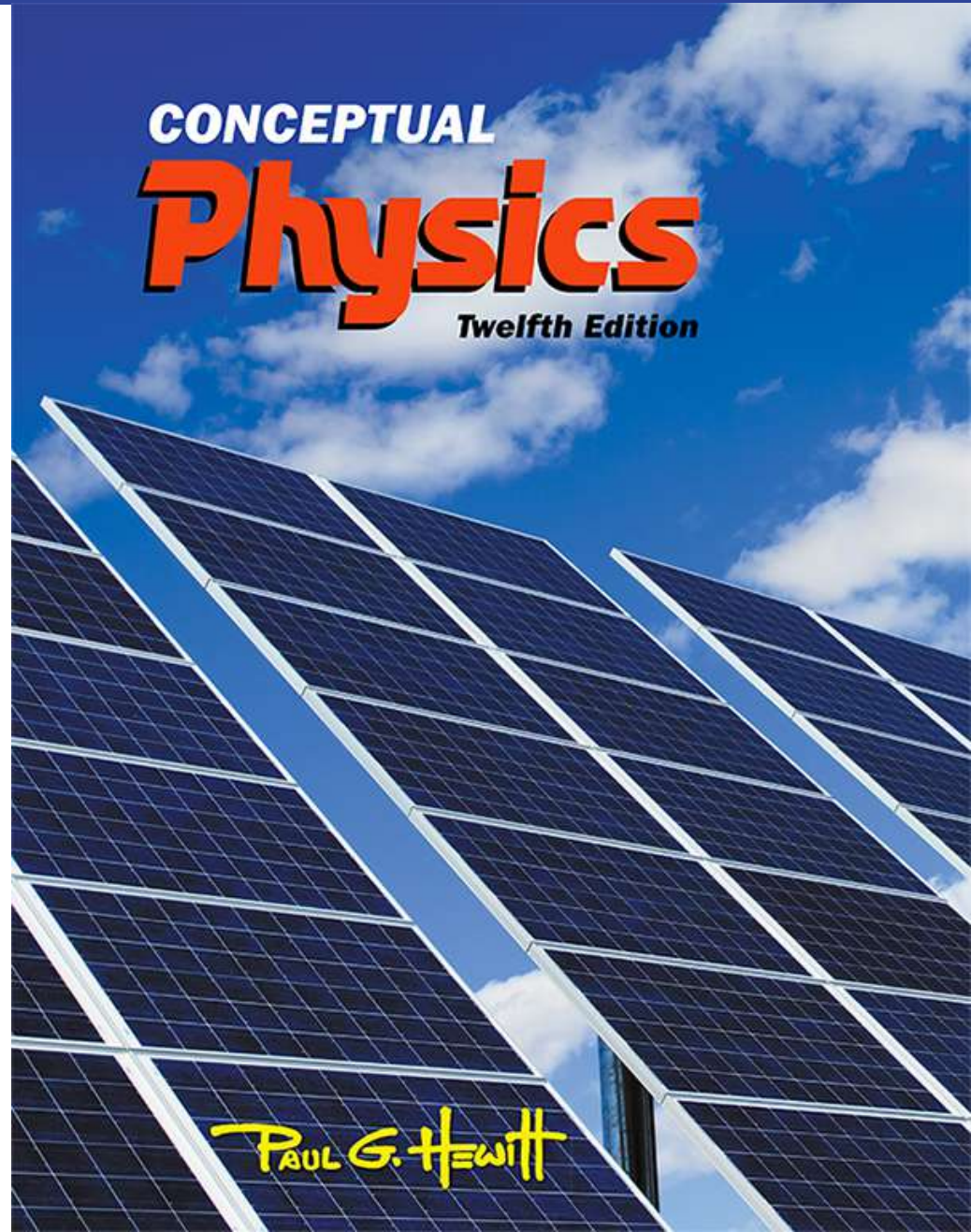


# Lecture Outline

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

### Part 1



# Roentgen and the first x-ray:

Roentgen:



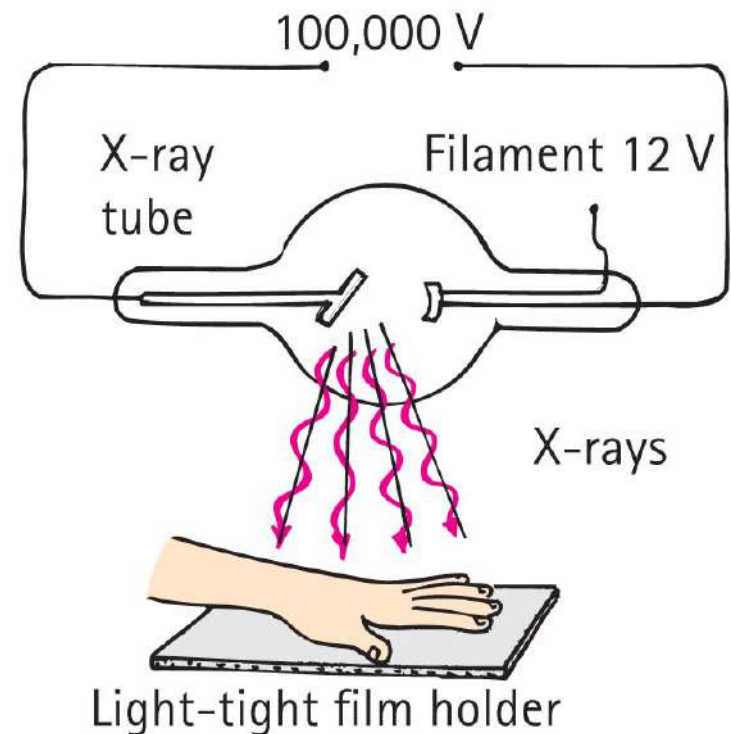
His wife's hand:



"I have seen my death!"

# 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.

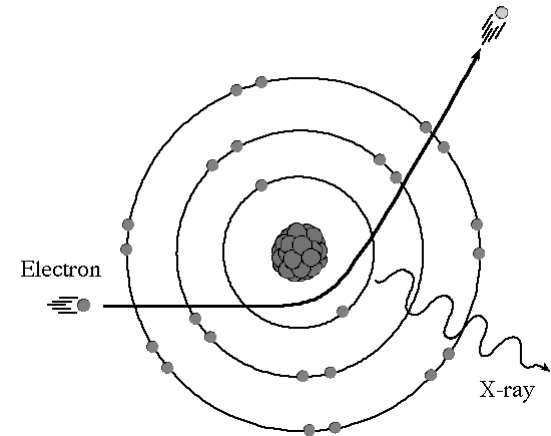


# Classwork

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

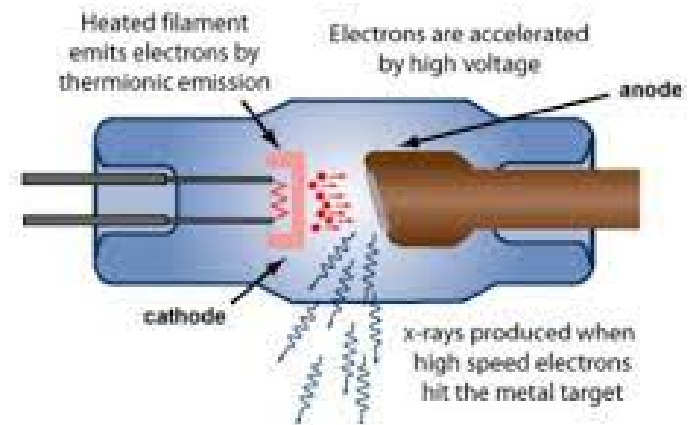
# X-Rays and Radioactivity, Continued

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).

Typical X-ray tube operation



# 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.

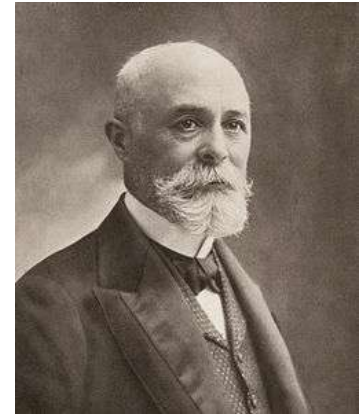


# Classwork:

2. What kind of rays are X-rays?

# 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!





# Classwork:

3. What did the Becquerel discover about uranium?

# 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.



# Classwork:

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

# • 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.

# **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.

# **X-Rays and Radioactivity**

## **CHECK YOUR ANSWER**

The radioactive decay of nature's elements occurs in the

**D. All of the above.**

# 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.

# Alpha, Beta, and Gamma Rays

## CHECK YOUR ANSWER

The origins of radioactivity go back to

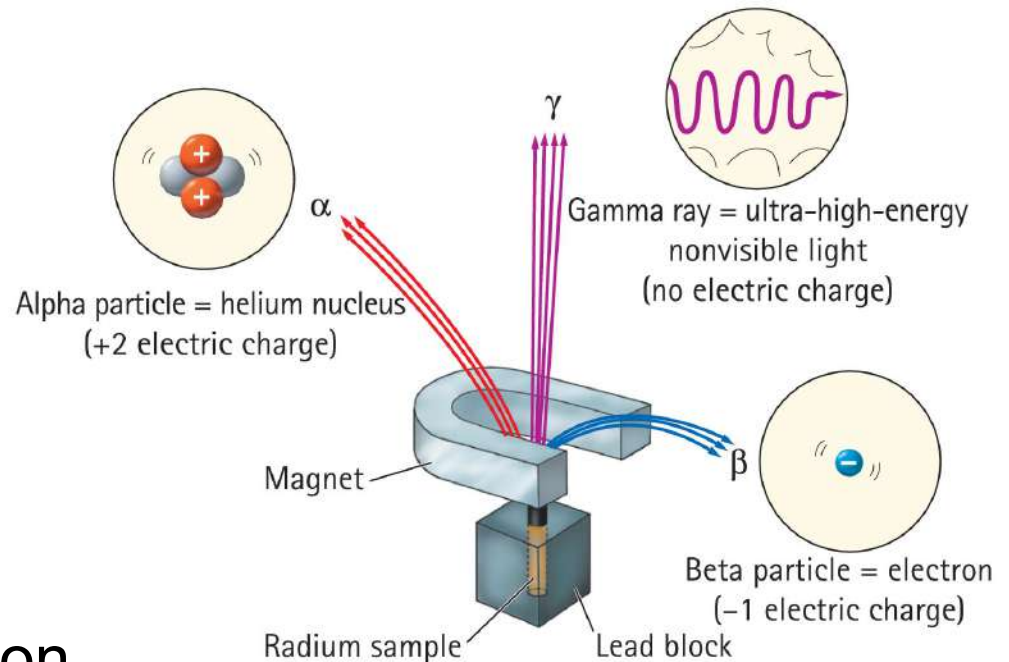
**D. before humans emerged on Earth.**



# Alpha, Beta, and Gamma Rays

- Radioactive elements emit three distinct types of radiation:

- $\alpha$  —alpha:  
positively charged  
(helium nuclei)
- $\beta$  —beta:  
negatively charged  
(electrons)
- $\gamma$  —gamma:  
electromagnetic radiation  
not charged, so they are not  
bent by a magnetic field

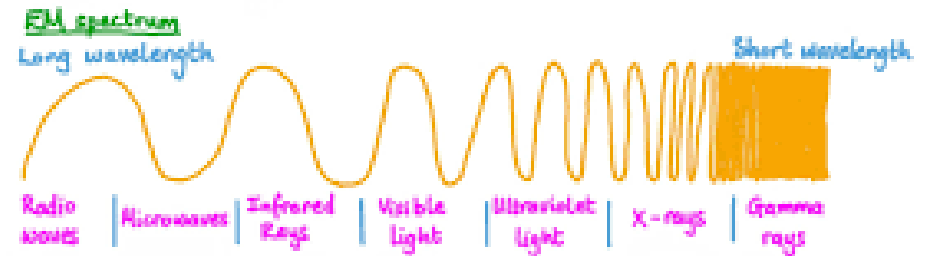


# Classwork

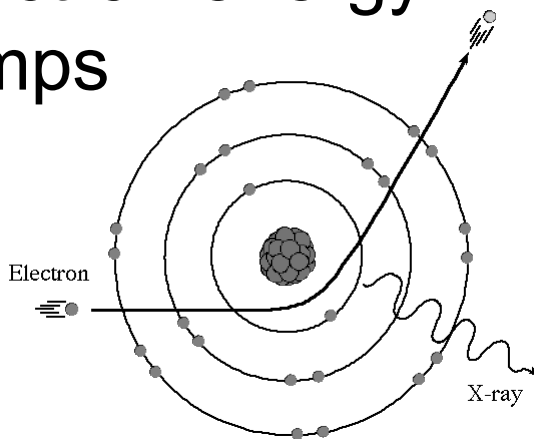
5. Why aren't gamma rays deflected in a magnetic field?

Gamma rays have more energy than x-rays.  
Why?

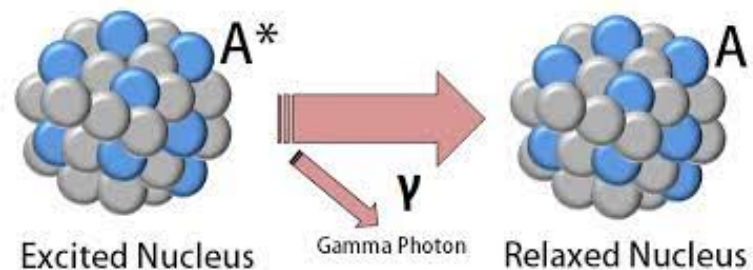
Which type of electromagnetic radiation has a shorter wavelength: gamma rays or X-rays? Gamma rays



**x-rays:** from electron energy jumps



**$\gamma$ -rays:** from nucleon energy jumps



Bigger energy jumps

→ higher photon energy

→  $E = hf$  → higher frequency

# Classwork

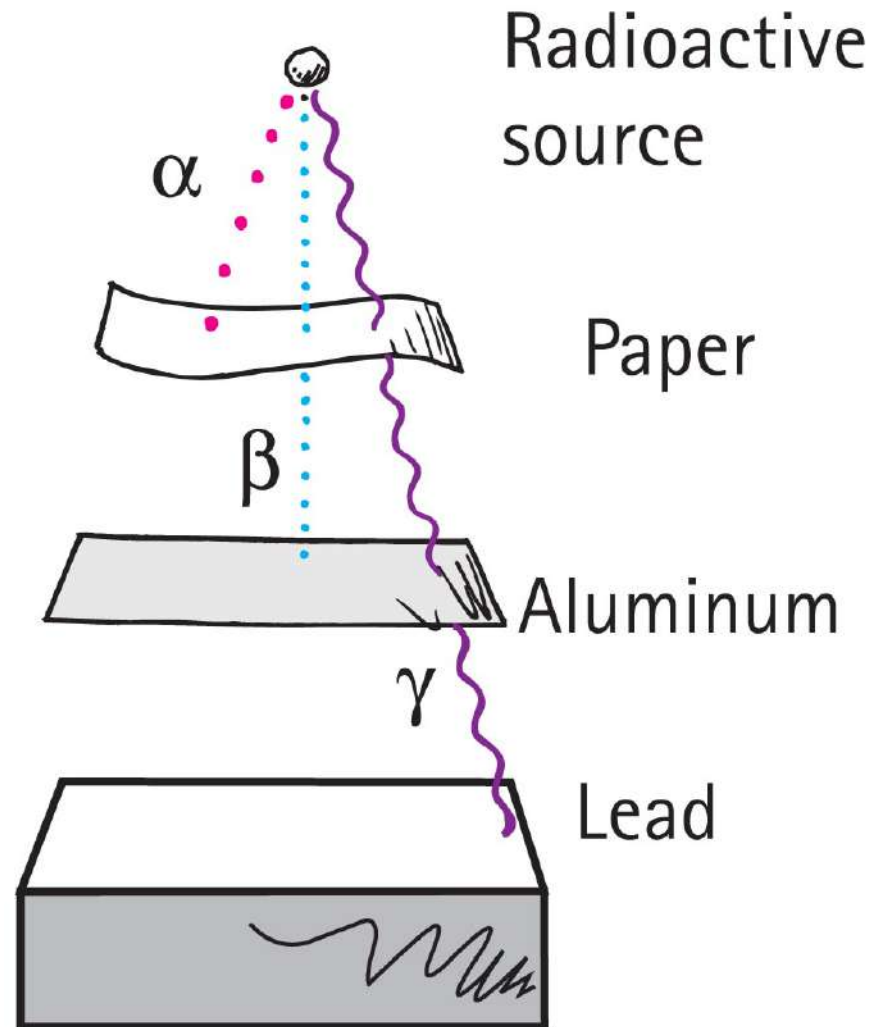
6. Which has the higher frequency: X-rays or gamma rays?

# Alpha, Beta, and Gamma Rays, Continued

- Relative penetrations:

$\alpha$ : easiest to stop

$\gamma$ : hardest to stop



## 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?

# 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.

# 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.



# 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.

# Alpha, Beta, and Gamma Rays

## CHECK YOUR ANSWER, Continued-1

Which of these is the nucleus of the helium atom?

**A. Alpha**

# 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.

# Alpha, Beta, and Gamma Rays

## CHECK YOUR ANSWER, Continued-2

Which of these is actually a high-speed electron?

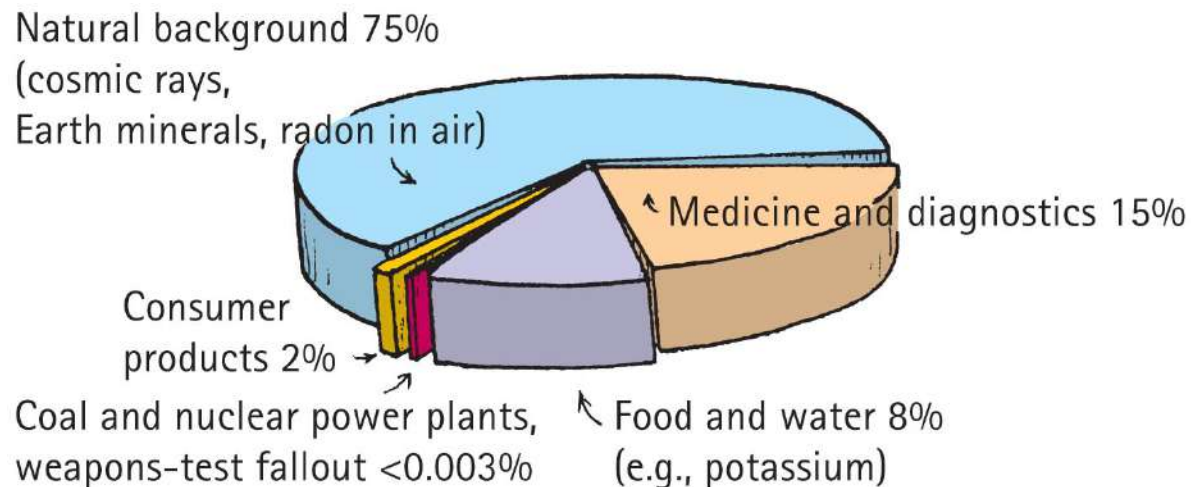
**B. Beta**

**Explanation:**

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

# Environmental Radiation

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

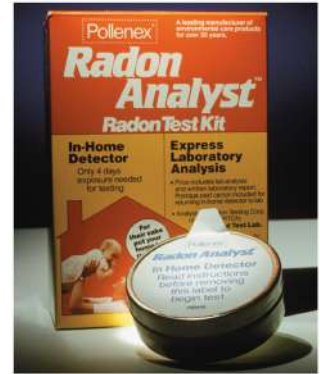
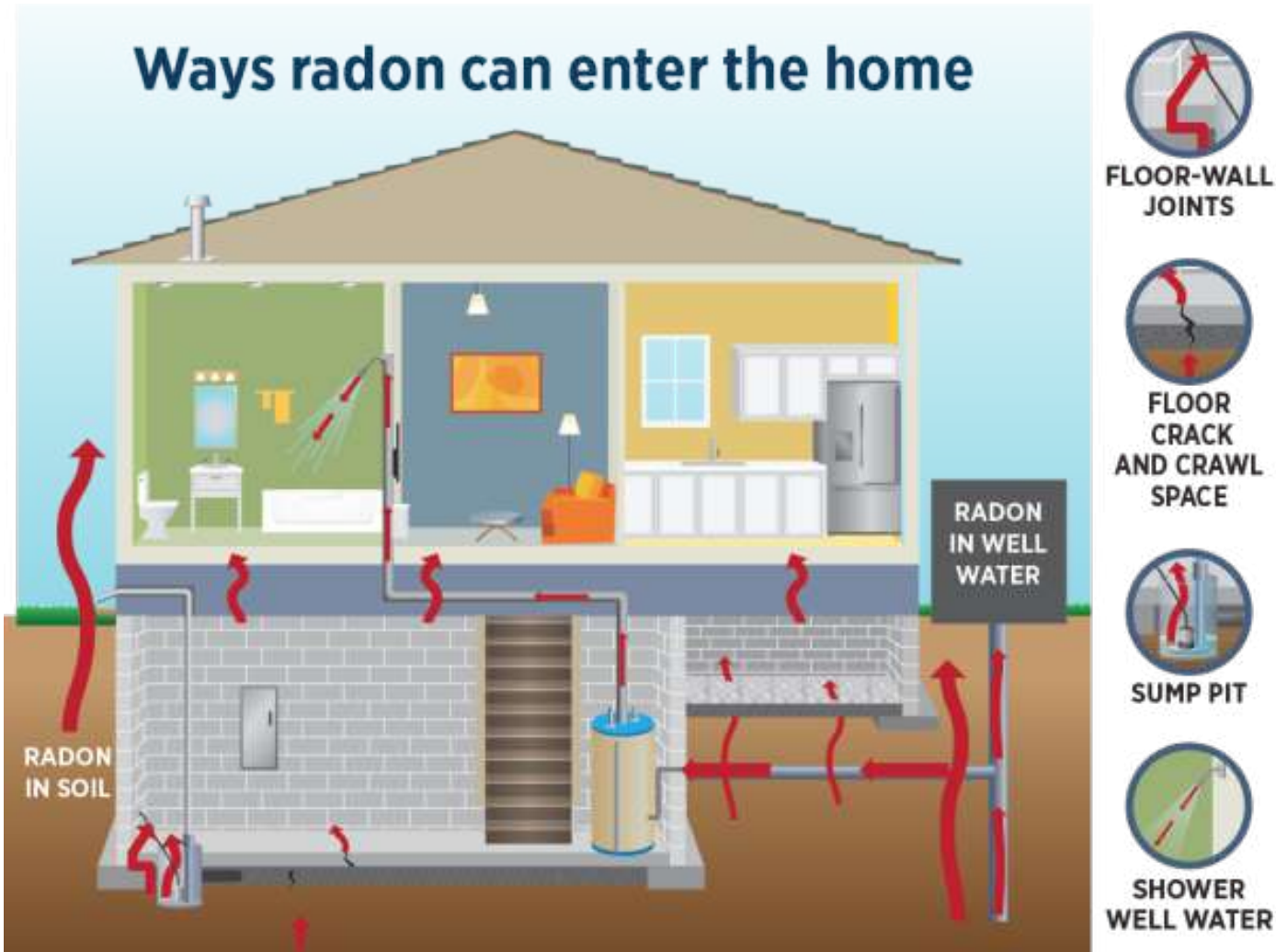


The combustion of coal releases about 13,000 tons of radioactive thorium and uranium into the atmosphere each year. The nuke power industry generates 10,000 tons of radioactive waste per year.

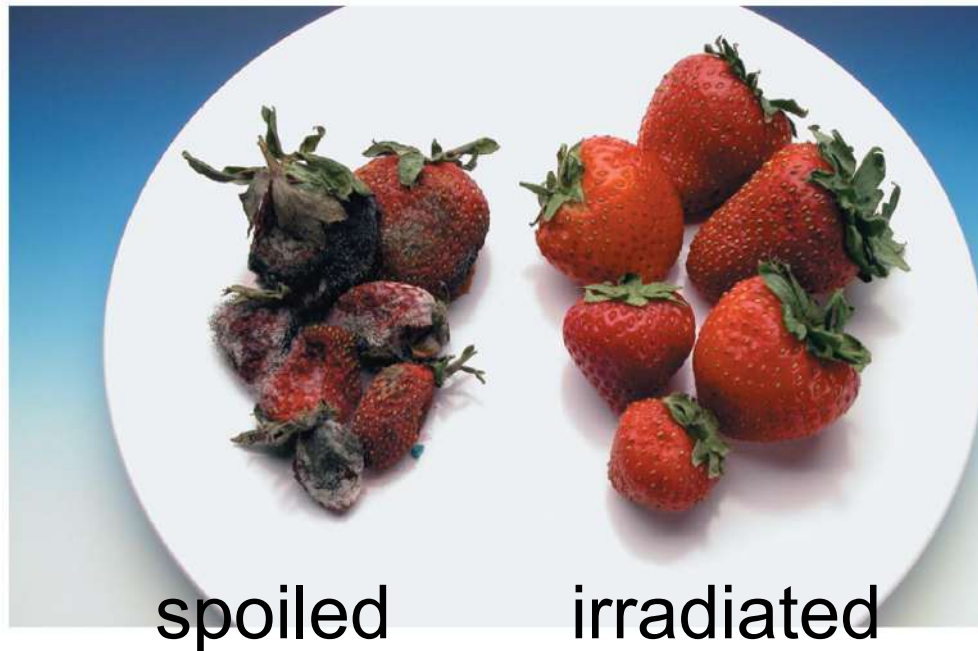
# Classwork

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

- Radon, a common environmental hazard



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





# 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.

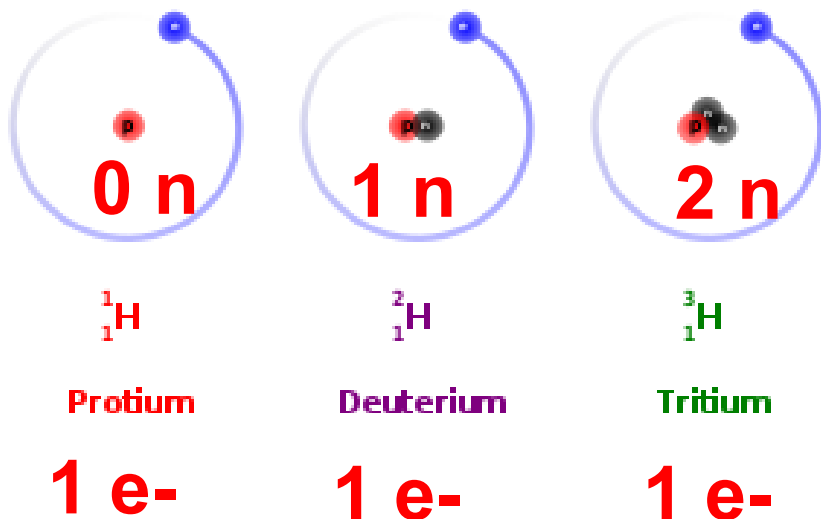
# Classwork

9. Is the human body radioactive? Explain.

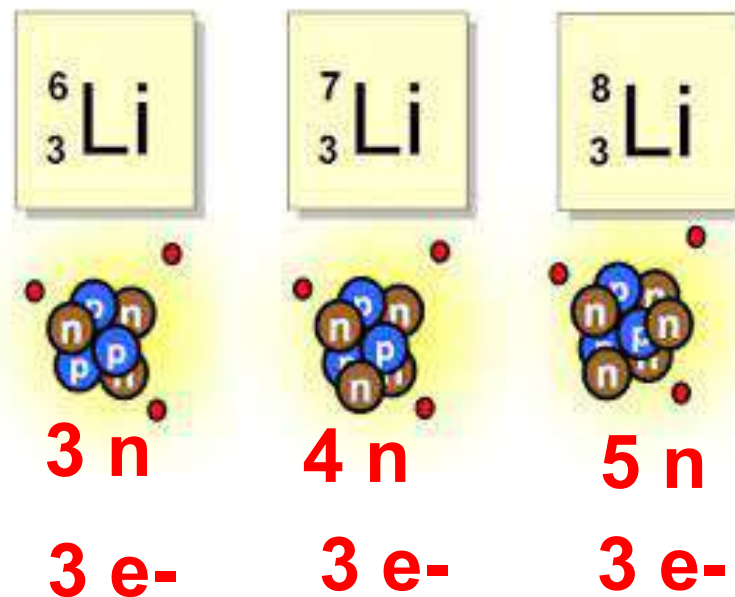
# Isotopes:

- 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:



→ 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.

# 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.

# 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.

# 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.

# 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.



# Periodic Table

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

## PERIODIC TABLE OF ELEMENTS

1

H

Hydrogen

Nonmetal

3

Li

Lithium

Alkali Metal

4

Be

Beryllium

Alkaline Earth Metal

11

Na

Sodium

Alkali Metal

12

Mg

Magnesium

Alkaline Earth Metal

19

K

Potassium

Alkali Metal

20

Ca

Calcium

Alkaline Earth Metal

21

Sc

Scandium

Transition Metal

22

Ti

Titanium

Transition Metal

23

V

Vanadium

Transition Metal

24

Cr

Chromium

Transition Metal

25

Mn

Manganese

Transition Metal

26

Fe

Iron

Transition Metal

27

Co

Cobalt

Transition Metal

28

Ni

Nickel

Transition Metal

29

Cu

Copper

Transition Metal

30

Zn

Zinc

Transition Metal

31

Ga

Gallium

Post-Transition Metal

32

Ge

Germanium

Metalloid

33

As

Arsenic

Metalloid

34

Se

Selenium

Nonmetal

35

Br

Bromine

Halogen

36

Kr

Krypton

Noble Gas

37

Rb

Rubidium

Alkali Metal

38

Sr

Strontium

Alkaline Earth Metal

39

Y

Yttrium

Transition Metal

40

Zr

Zirconium

Transition Metal

41

Nb

Niobium

Transition Metal

42

Mo

Molybdenum

Transition Metal

43

Tc

Technetium

Transition Metal

44

Ru

Ruthenium

Transition Metal

45

Rh

Rhodium

Transition Metal

46

Pd

Palladium

Transition Metal

47

Ag

Silver

Transition Metal

48

Cd

Cadmium

Transition Metal

49

In

Indium

Post-Transition Metal

50

Sn

Tin

Post-Transition Metal

51

Sb

Antimony

Metalloid

52

Te

Tellurium

Metalloid

53

I

Iodine

Halogen

54

Xe

Xenon

Noble Gas

55

Cs

Cesium

Alkali Metal

56

Ba

Barium

Alkaline Earth Metal

57

La

Lanthanum

Lanthanide

58

Ce

Cerium

Lanthanide

59

Pr

Praseodymium

Lanthanide

60

Nd

Neodymium

Lanthanide

61

Pm

Promethium

Lanthanide

62

Sm

Samarium

Lanthanide

63

Eu

Europium

Lanthanide

64

Gd

Gadolinium

Lanthanide

65

Tb

Terbium

Lanthanide

66

Dy

Dysprosium

Lanthanide

67

Ho

Holmium

Lanthanide

68

Er

Erbium

Lanthanide

69

Tm

Thulium

Lanthanide

70

Yb

Ytterbium

Lanthanide

71

Lu

Lutetium

Lanthanide

87

Fr

Francium

Alkali Metal

88

Ra

Radium

Alkaline Earth Metal

89

Ac

Actinium

Actinide

90

Th

Thorium

Actinide

91

Pa

Protactinium

Actinide

92

U

Uranium

Actinide

93

Np

Neptunium

Actinide

94

Pu

Plutonium

Actinide

95

Am

Americium

Actinide

96

Cm

Curium

Actinide

97

Bk

Berkelium

Actinide

98

Cf

Californium

Actinide

99

Es

Einsteinium

Actinide

100

Fm

Fermium

Actinide

101

Md

Mendelevium

Actinide

102

No

Nobelium

Actinide

103

Lr

Lawrencium

Actinide

113

Nh

Nihonium

Post-Transition Metal

114

Fl

Flerovium

Post-Transition Metal

115

Mc

Moscovium

Post-Transition Metal

116

Lv

Livermorium

Post-Transition Metal

117

Ts

Tennessine

Halogen

118

Og

Oganesson

Noble Gas

1

H

Hydrogen

Nonmetal

Atomic Number

Symbol

Name

Chemical Group Block

5

B

Boron

Metalloid

6

C

Carbon

Nonmetal

7

N

Nitrogen

Nonmetal

8

O

Oxygen

Nonmetal

9

F

Fluorine

Halogen

10

Ne

Neon

Noble Gas

13

Al

Aluminum

Post-Transition Metal

14

Si

Silicon

Metalloid

15

P

Phosphorus

Nonmetal

16

S

Sulfur

Nonmetal

17

Cl

Chlorine

Halogen

18

Ar

Argon

Noble Gas

81

Tl

Thallium

Post-Transition Metal

82

Pb

Lead

Post-Transition Metal

83

Bi

Bismuth

Post-Transition Metal

84

Po

Polonium

Metalloid

85

At

Astatine

Halogen

86

Rn

Radon

Noble Gas

Pb = lead

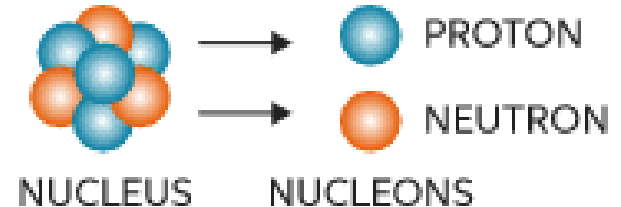
# Why are some atoms radioactive?

Some isotopes are radioactive. Others are not.

Why?

Look inside nucleus:

The nucleus contains *nucleons*:  
protons and neutrons



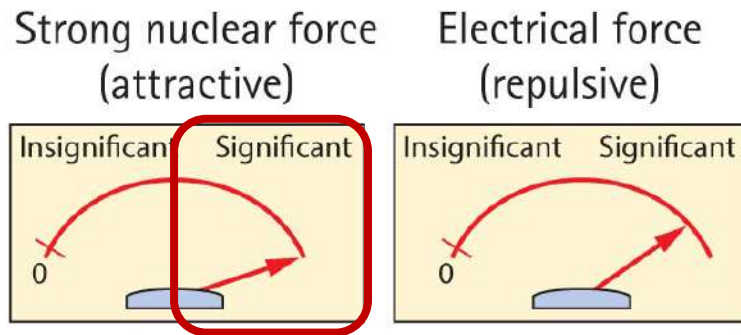
There are 2 forces that act on nucleons:

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.

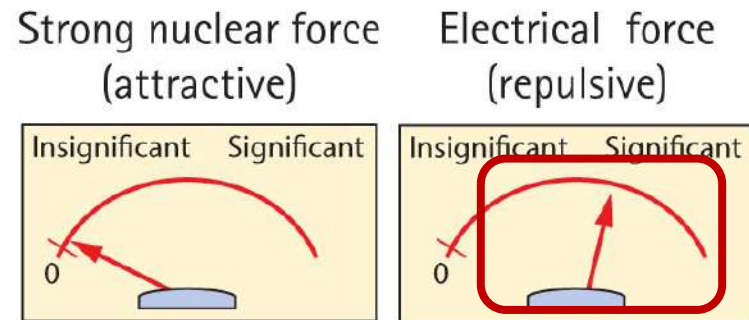
# Classwork

11. Name the two different nucleons.

- 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

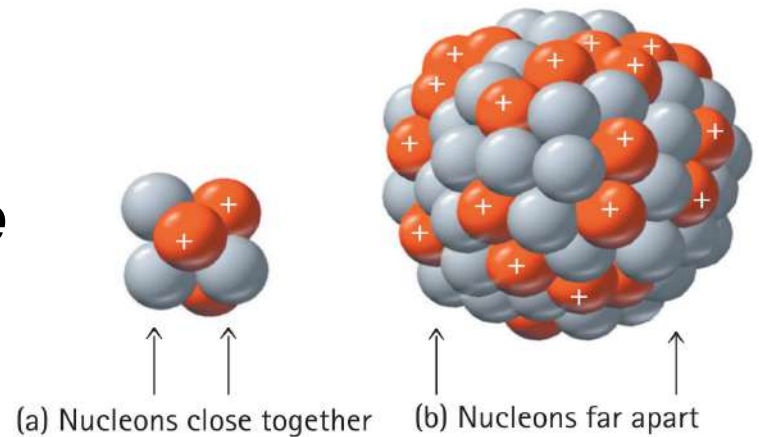


(a)      protons close  
strong force wins  
stable nucleus



(b)      protons far apart  
electric force wins  
unstable nucleus

- 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).

# Classwork

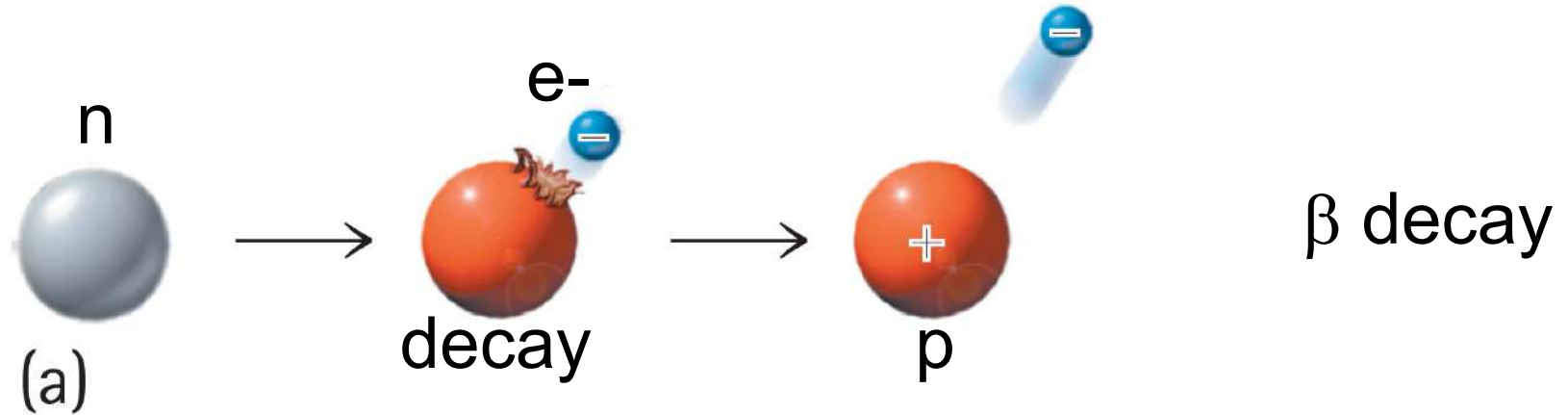
12. Why doesn't the repulsive electrical force of protons in the atomic nucleus cause the protons to fly apart?

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?

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



This can be written as an equation:

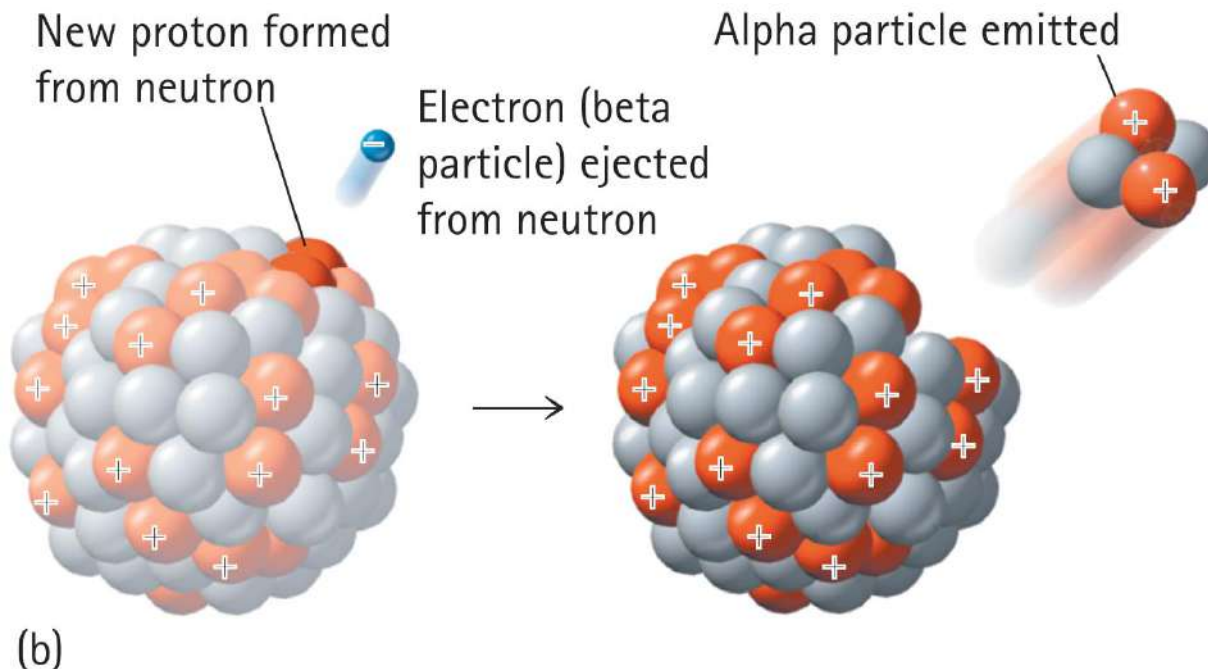


The arrow  $\rightarrow$  means “decays into”

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

## 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  $\alpha$  particle:





# 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.

# The Atomic Nucleus and the Strong Force

## CHECK YOUR ANSWER

The strong force is a force in the

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

# 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.

# 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.**