Name Date

Section
7.1
Summary

Atomic Theory, Isotopes, and Radioactive Decay

Textbook pages 286–301

Before You Read

Radiation is used for many purposes. What uses of radiation are you already aware of? Write your response in the lines below.

____

____

Create a Quiz

After you have read this section, create a five-question quiz based on what you have learned. Answer the questions until you get each one correct.

What is radioactivity?

Radioactivity is the release of high-energy particles and rays of energy from a substance as a result of changes in the nuclei of its atoms. **Radiation** refers to high-energy rays and particles emitted by radioactive sources, including radio waves, microwaves, infrared rays, visible light, and ultraviolet rays, that are found on the electromagnetic spectrum. **Light** is a form of radiation that humans can see.

What are isotopes?

Isotopes are different atoms of a particular element that have the same number of protons but different numbers of neutrons. The **mass number** of an atom is an integer (whole number) that represents the sum of the atom's protons and neutrons—so isotopes have different mass numbers. The mass number of an isotope is found by adding the atomic number (number of protons) to the number of neutrons.

Mass number = atomic number + number of neutrons

To find the number of neutrons of an isotope, subtract the atomic number from the mass number.

Number of neutrons = mass number – atomic number

Reading Check

Write the equation used to calculate mass number.

____

How are isotopes represented?

Chemists represent isotopes using standard atomic notation (also called the **nuclear symbol**), a shortened form involving the chemical symbol, atomic number, and mass number. The mass number is written as a superscript (above) on the left of the symbol. The atomic number is written as a subscript (below), also on the left.

$${}^{39}_{19}\mathrm{K}$$

The mass number of this potassium isotope is 39. The atomic number is 19. An isotope of potassium with a mass number of 39 can also be represented as potassium-39, or K-39

What is radioactive decay?

By emitting radiation, atoms of one kind of element can change into atoms of another element. Radioactive atoms emit radiation because their nuclei are unstable. Unstable atoms gain stability by losing energy. **Radioactive decay** is the process in which unstable nuclei lose energy by emitting radiation. Unstable radioactive atoms undergo radioactive decay and form stable, non-radioactive atoms, usually of a different element. **Radioisotopes** are natural or human-made isotopes that decay into other isotopes, releasing radiation.

What different types of radiation are emitted during radioactive decay?

The three major types of radiation are alpha radiation, beta radiation, and gamma radiation. Their properties are summed up in the following table: ✔

Reading Check

Name the three main types of radiation.

____

____

____

Table 7.3 Properties of Alpha, Beta, and Gamma Radiation

Property	Alpha Radiation	Beta Radiation	Gamma Radiation
Symbol	${}^4_2a$ or ${}^4_2He$	${}^0_{-1}b$ or ${}^0_{-1}e$	${}^0_0c$
Composition	Alpha particles	Beta particles	High-energy electromagnetic radiation
Description of radiation	Helium nuclei, ${}^4_2He$	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

How is radioactive decay expressed?

Radioactivity results when the nucleus of an atom decays. There are three radioactive decay processes:

1. Alpha decay: The emission of an **alpha particle** (the same particles found in the nucleus of a helium atom) from a nucleus is a process called **alpha decay.** When a radioactive nucleus emits an alpha particle, the atomic number of the product nucleus is reduced by two, and its mass number by four. However, the sum of the atomic numbers and the sum of the mass numbers on each side of the arrow remain equal.

$${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\alpha$$

2. Beta decay: In **beta decay**, a neutron changes into a proton and a **beta particle**, an electron. The proton remains in the nucleus while the electron leaves the nucleus. Since the proton remains in the nucleus, the atomic number of the element increases by one—it has become an atom of the next higher element on the periodic table. However, its mass number does not change, as a proton of almost equal mass has replaced the neutron.

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

3. Gamma decay: **Gamma decay** results from a redistribution of energy within the nucleus. **Gamma radiation** consists of rays of high-energy, short-wavelength radiation. A gamma ray is given off as the isotope changes from a high-energy state to a lower energy state.

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

The "*" means that the nickel nucleus has extra energy that is released as a gamma ray.

Use with textbook pages 289–293.

Isotopes

1. What is an isotope?

____

2. Atomic number + number of neutrons = ________________

3. Number of protons + number of neutrons = ________________

4. Mass number – atomic number = ________________

Use the following standard atomic notation of an isotope to answer questions 5 to 7.

________________ → 13
________________ → 5

$^{13}_{5}\text{B}$

5. Label the mass number and the atomic number.

6. What is the name of this isotope? ________________

7. Determine the number of subatomic particles for this isotope:

(a) number of protons = ________________

(b) number of electrons = ________________

(c) number of neutrons = ________________

8. In each of the following cases, what element does the symbol X represent and how many neutrons are in the nucleus?

(a) $^{21}_{10}\text{X}$

Element = ________________

Number of neutrons = ________

(b) $^{32}_{16}\text{X}$

Element = ________________

Number of neutrons = ________

(c) $^{230}_{89}\text{X}$

Element = ________________

Number of neutrons = ________

(d) $^{234}_{90}\text{X}$

Element = ________________

Number of neutrons = ________

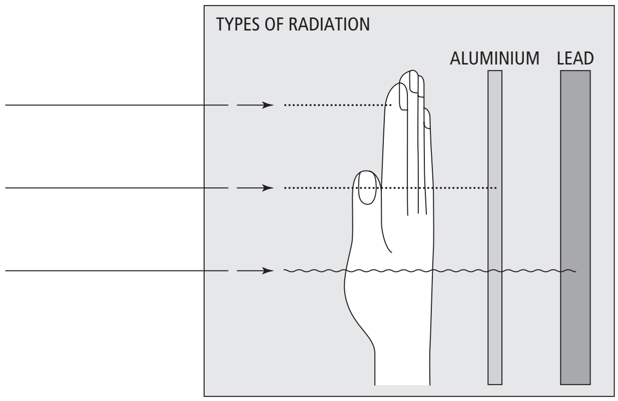
9. Complete the following table. The first row has been completed to help guide you.

Isotope	Standard atomic notation	Atomic number	Mass number	Number of protons	Number of neutrons
carbon-14	${}^{14}_{6}C$	6	14	6	8
		27	52		
nickel-60					
			1 4	7	
thallium-201					
	${}^{226}_{88}Ra$				
				82	126

Use with textbook pages 294–297.

Alpha, beta, and gamma radiation

1. Label the following diagram. Identify the penetrating power of the three forms of radioactive decay products: alpha particle, beta particle, and gamma ray.



2. Indicate whether the description is referring to an alpha particle, a beta particle, or a gamma ray. The description can refer to more than one of the forms of radiation.

(a) ${}^{0}_{0}\gamma$ ______________________

(b) ${}^{0}_{-1}\beta$ or ${}^{0}_{-1}e$ ______________________

(c) ${}^{4}_{2}\alpha$ o+++r ${}^{4}_{2}$He ______________________

(d) has a charge of 0 ______________________

(e) has a charge of 1- ______________________

(f) has a charge of 2+ ______________________

(g) is a helium nucleus ______________________

(h) is a high-speed electron ______________________

(i) is emitted from the nucleus ______________________

(j) is emitted only during beta decay ______________________

(k) is emitted only during alpha decay ______________________

(l) can be stopped by aluminum foil ______________________

(m) is emitted only during gamma decay ______________________

(n) is affected by electric and magnetic fields ______________________

(o) is not affected by electric and magnetic fields ______________________

(p) is a high energy wave with short wavelengths ______________________

(q) is the highest energy form of electromagnetic radiation ______________________

(r) has low penetrating power (can be stopped by a single piece of paper) ______________________

(s) has the greatest penetrating power (can only be stopped by lead or concrete) ______________________

Name ____________________ Date ____________________

Applying Knowledge
Section 7.1

Use with textbook pages 286–299.

Radioactive decay and nuclear equations

> Remember the following two rules when working with nuclear equations:
> **I.** The sum of the mass numbers does not change.
> **II.** The sum of the charges in the nucleus does not change.

Identify each nuclear equation as alpha decay, beta decay, or gamma decay, and then complete the nuclear equation.

1. ${}^{32}_{15}\mathrm{P}$ -----> ${}^{32}_{16}\mathrm{S}$ + ________ ____________________
2. ${}^{218}_{84}\mathrm{Po}$ -----> ________ + ${}^{4}_{2}\mathrm{He}$ ____________________
3. ________ -----> ${}^{18}_{5}\mathrm{Ar}$ + ${}^{0}_{-1}e$ ____________________
4. ${}^{24}_{12}\mathrm{Mg}^{*}$ -----> ________ + ${}^{0}_{0}\gamma$ ____________________
5. ${}^{234}_{91}\mathrm{Pa}$ -----> ________ + ${}^{4}_{2}\alpha$ ____________________
6. ${}^{141}_{58}\mathrm{Ce}$ -----> ________ + ${}^{0}_{-1}e$ ____________________
7. ${}^{216}_{84}\mathrm{Po}$ -----> ________ + ${}^{0}_{-1}\beta$ ____________________
8. ${}^{20}_{9}\mathrm{F}$ -----> ${}^{20}_{10}\mathrm{Ne}$ + ________ ____________________
9. ${}^{58}_{26}\mathrm{Fe}^{*}$ -----> ${}^{58}_{26}\mathrm{Fe}$ + ________ ____________________
10. ________ -----> ${}^{221}_{87}\mathrm{Fr}$ + ${}^{4}_{2}\alpha$ ____________________
11. ${}^{149}_{64}\mathrm{Gd}^{*}$ -----> ________ + ${}^{0}_{0}\gamma$ ____________________
12. ${}^{226}_{86}\mathrm{Ra}$ -----> ${}^{222}_{26}\mathrm{Rn}$ + ________ ____________________
13. ________ -----> ${}^{212}_{82}\mathrm{Pb}$ + ${}^{0}_{-1}\beta$ ____________________
14. ${}^{214}_{83}\mathrm{Bi}$ -----> ${}^{210}_{81}\mathrm{Tl}$ + ________ ____________________
15. ________ -----> ${}^{254}_{98}\mathrm{Cf}$ + ${}^{0}_{0}\gamma$ ____________________

Use with textbook pages 286–299.

Atomic theory, isotopes, and radioactive decay

Match the Descriptor on the left with the best Scientist on the right. Each Scientist may be used more than once.

Descriptor	Scientist
1. ______ discovered X-rays	**A.** Marie Curie
2. ______ identified polonium and radium	**B.** Henri Becquerel
3. ______ first to identify alpha, beta, and gamma radiation	**C.** Ernest Rutherford
4. ______ discovered the nucleus and created a model of the atom	**D.** Wilhelm Roentgen
5. ______ discovered that uranium salts emitted rays that darkened photographic plates	

6. Which of the following electromagnetic radiations has the highest frequency and energy?

A. X-rays

B. gamma rays

C. microwaves

D. ultraviolet radiation

7. The number of neutrons in an atom is found by

A. adding the atomic number to the mass number

B. subtracting the mass number from the atomic number

C subtracting the atomic number from the mass number

D. adding the number of protons to the number of electrons

8. What is used to tell different isotopes of a particular element apart?

A. the mass number

B. the atomic number

C. the number of protons

D. the number of electrons

9. One isotope of polonium is $^{212}_{84}Po$. Any other isotope of polonium must have

A. 84 protons

B. 128 protons

C. 84 neutrons

D. 128 neutrons

10. How many protons, neutrons, and electrons are in the isotope calcium-42, $^{42}_{20}Ca$?

	Protons	Neutrons	Electrons
A.	20	22	20
B.	20	20	22
C.	22	22	20
D.	22	20	20

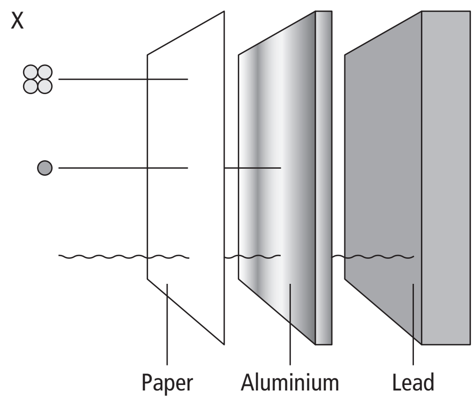
Use the following standard atomic notation for the lithium isotope to answer question 11.

7 **Li** 3

11. What does each part of the standard atomic notation shown above represent?

	"3"	"7"
A.	atomic number	mass number
B.	mass number	atomic number
C.	number of neutrons	number of protons
D.	number of protons	number of electrons

Use the following diagram showing the penetrating power of a type of radiation to answer question 12.



12. What does "X" represent?

A. a gamma ray

B. a beta particle

C. an alpha particle

D. a high-speed electron

13. Which type of radioactive decay process results in no change to the nucleus?

A. beta decay

B. alpha decay

C. gamma decay

14. The symbol ${}^{4}_{2}He$ is equivalent to which of the following?

A. ${}^{0}_{-1}e$

B. ${}^{0}_{-1}\beta$

C. ${}^{0}_{0}\gamma$

D. ${}^{4}_{2}\alpha$

15. Which of the following represents a beta decay?

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

B. ${}^{60}_{28}Ni^{*} \rightarrow {}^{60}_{28}Ni + {}^{0}_{0}\gamma$

C. ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$

D. ${}^{231}_{91}Pa \rightarrow {}^{227}_{89}Ac + {}^{4}_{2}He$

Use the following incomplete nuclear equation to answer question 16.

$${}^{144}_{60}NdI \rightarrow \_\_\_\_ + {}^{4}_{2}\alpha$$

16. What is product of this decay process?

A cobalt-58

B. cerium-58

C. cerium-140

D. samarium-62

