B.C. Science PROBE 10

Student Workbook

AUTHORS

Barry LeDrew

Jim Axford

Allan Carmichael

Doug Fraser

Karen Morley

John Munro

Darrell Scodellaro

PROGRAM CONSULTANT

Barry LeDrew

NELSON EDUCATION

UNIT C

Radioactivity

Contents

Chapter 10 Radioactivity

WS 10.1-1 Study Guide 1
WS 10.1-2 Radioactivity and Its History 2
WS 10.2-1 Study Guide—Radioactivity and the Nucleus 3
WS 10.2-2 Radioactivity and the Nucleus 4
WS 10.3-1 Study Guide—Radioactive Decay 6
WS 10.3-2 Radioactive Decay 8
WS 10.4-1 Study Guide—Half-Life 10
WS 10.4-2 Half-Life 11
WS 10.4-3 Half-Life Calculations 12
WS 10.4-4 TechConnect: Brachytherapy 13
WS 10.0-1 Matching Challenge: Radioactivity 14
WS 10.0-2 Chapter Checklist 15
WS 10.0-3 Worksheet: Test-Taking Strategies 16
Chapter 10 Quiz 18

Name: _____ Date: _____ 10.1

Study Guide—Radioactivity and Its History

Main Ideas–Use the space below to make notes on the main ideas of this section.

Sir J. J. Thomson determined that the rays emitted in a cathode ray tube are electrons.	
Wilhelm Röntgen discovered that when electrons strike a metal plate some of the kinetic energy is converted into X-rays, a high-energy component of the electromagnetic spectrum. Today, X-rays are used in the diagnosis and treatment of various diseases	
Henri Becquerel discovered that uranium emitted other rays which became known as Becquerel rays.	
Pierre and Marie Curie found that other minerals produced Becquerel rays and concluded that the rays came from the core of the atoms.	
Marie Curie coined the term **radioactivity** to describe the spontaneous emission of radiation from the nucleus of an atom.	

Vocabulary–Use the space below to write each definition in your own words.

radioactivity	

Radioactivity Timeline

Complete the timeline below by filling in the significant achievements in radioactivity that occurred in each year. Be sure to include the name of the scientist who made the important discovery.

1895 1896 1897 1898

Name: _____ Date: _____ 10.1

Radioactivity and Its History

Key Question: How have discoveries related to radioactivity built on earlier discoveries?

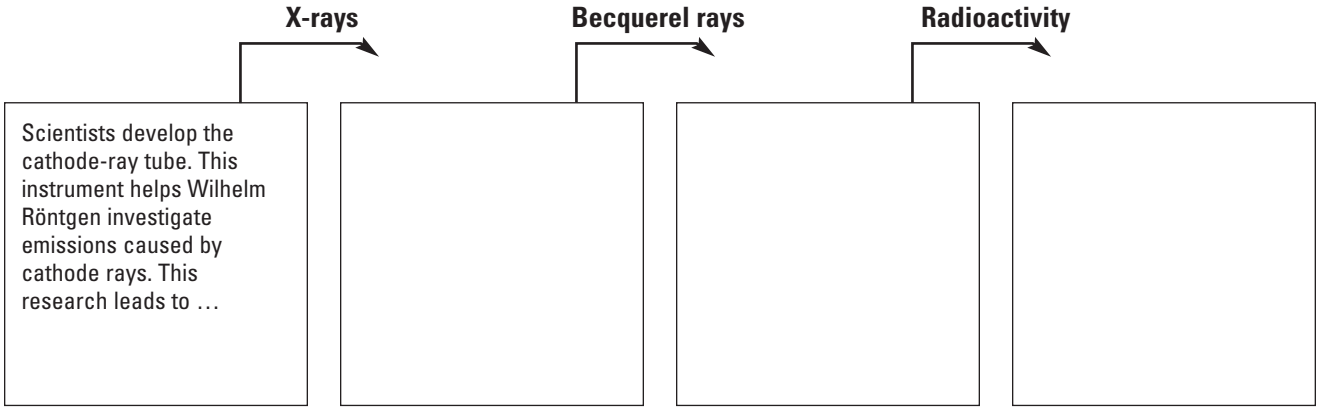
Before You Read

Study the timeline shown on page 275. Complete the chart below using the timeline as your only source.

Statement	True or false?	If false, restate as a true sentence
Scientists developed the most commonly accepted model of an atom nearly one hundred years ago.		
The development of the cathode-ray tube had little to do with James Chadwick's study of neutrons in the 1930s.		
Scientists were aware of radioactive elements before the turn of the 20th century.		

While You Read

While you read the section, use the chart below to describe how each scientific discovery led to the next.



After You Read

In your notebook, write a paragraph summarizing the history of radioactivity. Then, share your summary with a partner. Look for important points in your partner's summary that you may have missed in your own. Then, revise your own summary.

Name: _____ Date: _____ 10.2

Study Guide—Radioactivity and the Nucleus

Main Ideas–Use the space below to make notes on the main ideas of this section.

The first working model of an atom was called the "raisin bun" model because it involved electrons suspended in a mass of positive charge.	
Ernest Rutherford's gold foil experiment provided data that supports the theory that atoms have a **nucleus.**	
In 1932, James Chadwick discovered that the nucleus of an atom contains not only **protons,** but **neutrons** as well.	
The standard notation of an **isotope** denotes the isotope's name, atomic number, and mass number. The standard notation for carbon is $^{12}_{6}C$.	
By using the standard notation of a particular isotope along with the Periodic Table, we can determine the number of protons and neutrons the particular isotope has.	

Vocabulary–Use the space below to write each definition in your own words.

nucleus	
proton	
neutron	
isotope	

Practice Problem–Complete the problems in the space below.

Isotope	Complete notation and number of protons and neutrons	Isotope	Complete notation and number of protons and neutrons
zirconium-89	^{89}Zr protons _____ neutrons _____	xenon-118	^{118}Ze protons _____ neutrons _____
aluminum-24	^{24}Al protons _____ neutrons _____	cesium-137	^{137}Cs protons _____ neutrons _____

Name: _____ Date: _____ 10.2

Radioactivity and the Nucleus

Key Question: What did Rutherford's experiment reveal about the structure of the nucleus?

Before You Read

Many of the terms used in nuclear chemistry are used in other branches of science. You may have heard some of them already, and you may already know what some of them mean. Before you read, complete the following table of vocabulary terms using only what you already know. If you do not recognize a term, take your best guess at a definition.

Term	Have I heard this term before?	Definition
nucleus		
proton		
neutron		
isotope		

While You Read

By scanning a text quickly, you can get a good idea of what you will learn. As you read each page of this section, begin by scanning both the text and the illustrations. Then, answer the questions below.

Page 280

When Ernest Rutherford directed a narrow beam of particles toward gold foil, what unexpected result led him to conclude that each atom contains a nucleus?

_____

_____

Page 281

In what way is Rutherford's planetary model of an atom flawed?

_____

_____

Identify two ideas of atomic theory listed on this page.

_____

_____

Name: _____ Date: _____ 10.2

Radioactivity and the Nucleus (continued)

Page 282
This page shows three different isotopes of carbon. In what way are the isotopes different from one another?

_____

_____

After You Read

In the space below, draw and label your own version of either the raisin-bun model or the planetary model of an atom. Then, write a paragraph describing the strengths and weaknesses of the model you chose to illustrate.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____ 10.3

Study Guide—Radioactive Decay

MAIN IDEAS–Use the space below to make notes on the main ideas of this section.

The nuclei of some naturally occurring elements are unstable and undergo **radioactive decay** by emitting radiation.	
Different types of radiation have different abilities to penetrate materials.	
In the process of transmutation an atom changes from one element to another. The **parent nucleus** changes to a **daughter nucleus.**	
Alpha decay occurs when an atom emits an alpha particle, which is really a helium nucleus having two protons and two neutrons.	
In beta decay, a neutron decays into a proton, an electron, and a neutrino. A beta particle is an electron, $_{-1}^{0}e$.	
A **gamma ray** is very high energy electromagnetic radiation. The emission of a gamma ray only changes the energy of the isotope.	

VOCABULARY–Use the space below to write each definition in your own words.

radioactive decay	
parent nucleus	
daughter nucleus	
alpha particle (α)	
beta particle (β)	
gamma ray (γ)	

Name: _____ Date: _____ 10.3

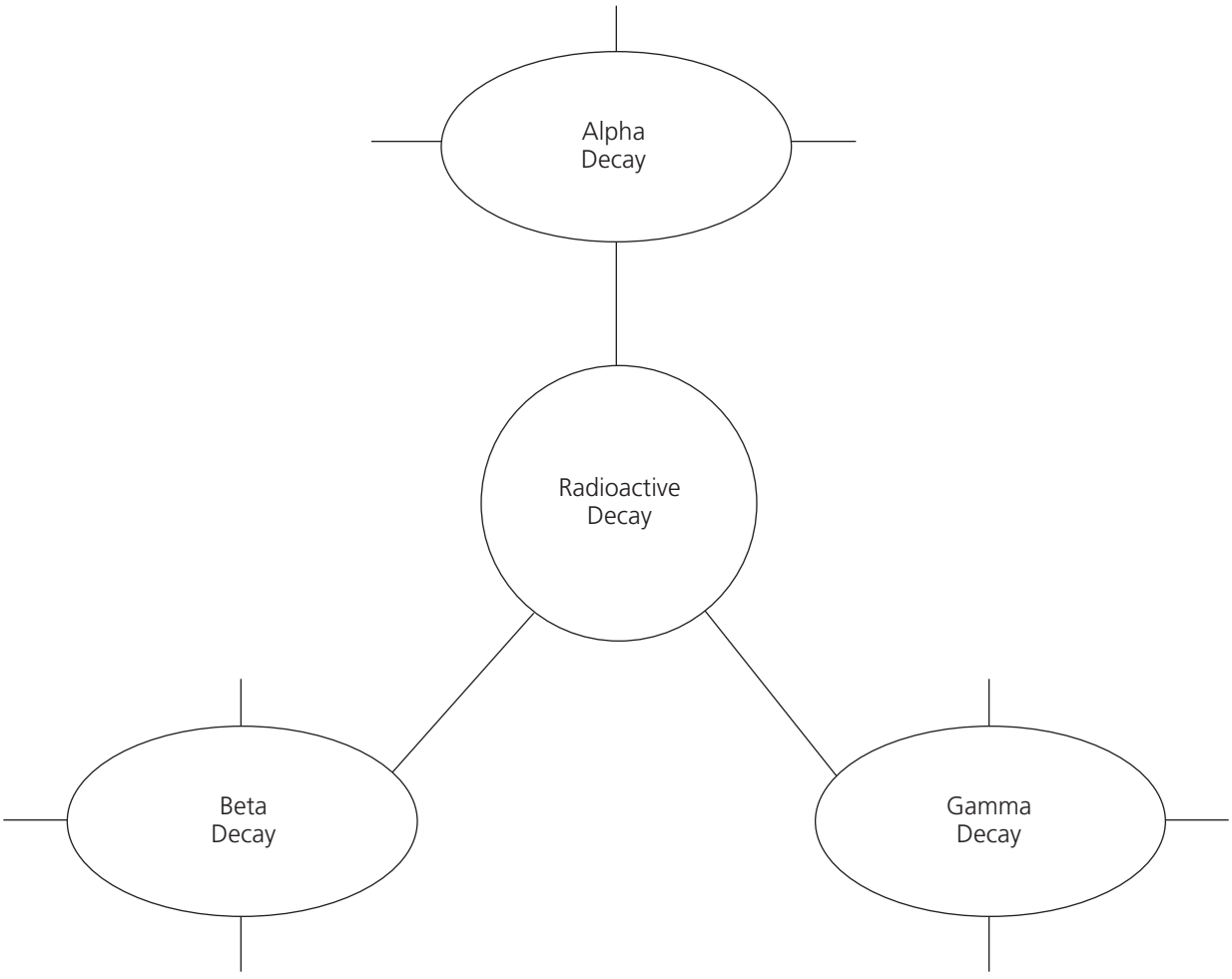
Study Guide (continued)

PRACTICE PROBLEMS–Complete the problems in the space below.

Radioactive Decay	Example	Practice
Alpha decay	$^{241}_{95}Am \longrightarrow {}^{237}_{93}Np + {}^{4}_{2}He$	$^{226}Ra \longrightarrow$
Beta decay	$^{137}_{55}Cs \longrightarrow {}^{137}_{56}Ba + {}^{0}_{-1}e$	$^{133}Xe \longrightarrow$
Gamma decay	$^{12}_{5}B \longrightarrow {}^{12}_{6}C^{*} + {}^{0}_{-1}e$ $^{12}_{6}C^{*} \longrightarrow {}^{12}_{6}C + {}^{0}_{0}\gamma$	$^{260}Co \longrightarrow$

CONCEPT WEB

Create your own summary of this section by completing the concept web.



Name: _____ Date: _____ 10.3

Radioactive Decay

Key Question: What are the results of alpha, beta, and gamma decay?

Before You Read

Complete the following table using information you can gather quickly from page 284 of Section 10.3. After you complete the table, follow the directions below.

Type of Radiation	What is it?	What can it pass through?
alpha particle		
beta particle		
gamma rays		

Based on the information you gathered in your table, which of the three types of radiation is likely the most dangerous for humans to be exposed to? Explain your answer.

_____

_____

_____

While You Read

Often in science, you will have to not only know formulas, but also apply those formulas to real-world situations.

A balanced nuclear equation depends on two factors: conservation of electric charge and conservation of mass number. In your own words, explain what these two rules mean.

Conservation of electric charge: _____

_____

Conservation of mass number: _____

_____

Name: _____ Date: _____ 10.3

Radioactive Decay (continued)

Check your understanding of the text by answering the following questions as you read.

During radioactive decay, some isotopes undergo transmutation while others do not. Explain why this is so.

In what way does gamma decay change the nucleus of an atom?

Would a Geiger counter be helpful in detecting the radiation given off by the decay of a sample of polonium-210? Explain how you know. (Hint: Refer to the alpha decay subsection in the student book.)

AFTER YOU READ

In the space below, provide a balanced nuclear equation to represent each of the three types of radioactive decay. Under each equation, describe in your own words the process each equation represents.

Alpha Decay

Beta Decay

Gamma Decay

Name: _____ Date: _____ 10.4

Study Guide—Half-Life

MAIN IDEAS–Use the space below to make notes on the main ideas of this section.

The rate of radioactive decay of a sample is largely unaffected by conditions outside the atoms of the sample.	
The decay rate of a sample is directly related to the number of parent nuclei in the sample.	
The number of decays a sample undergoes per second is known as the sample's activity. Activity is measured in becquerels.	
Radioactive parent nuclei in a sample decay at a predictable rate known as the **half-life.** The half-life is the average time it takes for half the parent nuclei in a sample of decay.	
Sometimes, the daughter nucleus of a unstable parent nucleus is also unstable. The daughter nucleus can therefore decay to form a different daughter nucleus. A Sequence of decay events is called a **decay series.** The decay series ends when a stable isotope forms.	
Because decay rates and half-lives are constant for a given isotope, the ratio of parent isotope to daughter isotope in the sample can be used to determine the age of the sample itself.	
Different isotopes have different decay rates. Therefore, some isotopes are more appropriate for radioactive dating of specific objects than others.	

VOCABULARY–Use the space below to write each definition in your own words.

half-life	
decay series	

PRACTICE PROBLEMS–Complete the problems in the space below.

Fraction or Percentage of Original Carbon-14 Remaining in Sample	Approximate Age of Sample
$\frac{1}{16}$	
	11 460 years
3.125 %	

Name: _____ Date: _____ 10.4

Half-Life

Key Question: What is the relationship between radioactive decay and half-life?

Before You Read

Skim through Section 10.4. Pay particular attention to the headings as you skim. After you finish, predict what you expect to learn as you read Section 10.4. Write your prediction on the lines below.

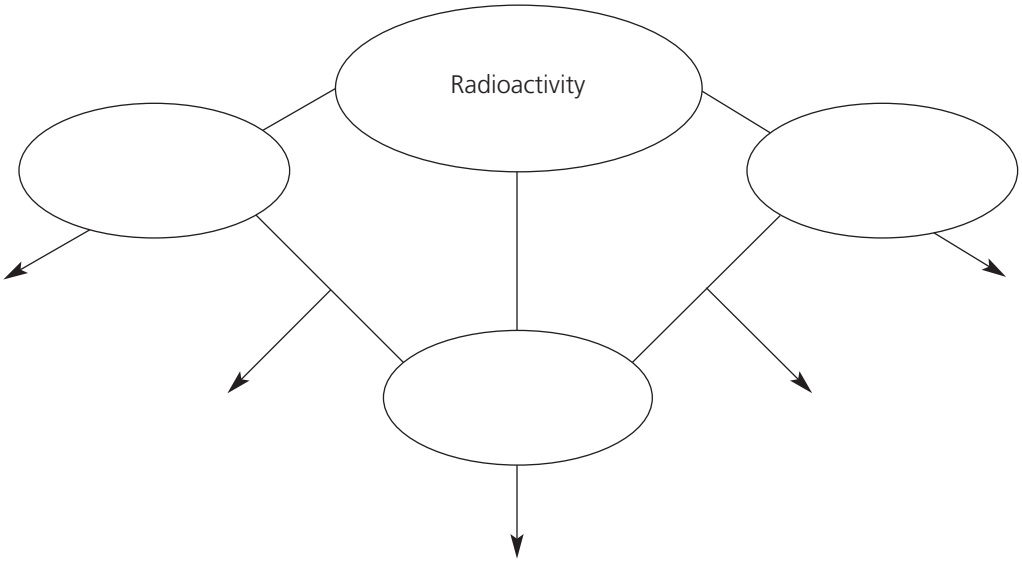
_____

_____

_____

While You Read

Complete the concept map.
In the bubbles, include the following terms: half-life, radioactive decay, and activity level. After each arrow, write a phrase or sentence describing the item and how it relates to the other items.



After You Read

Review your predictions in the Before You Read section. How accurate were your predictions? What did you learn that you did not expect to learn?

_____

_____

_____

Name: _____ Date: _____ 10.4

Half-Life Calculations

Solve each of the problems below. Show all your work.

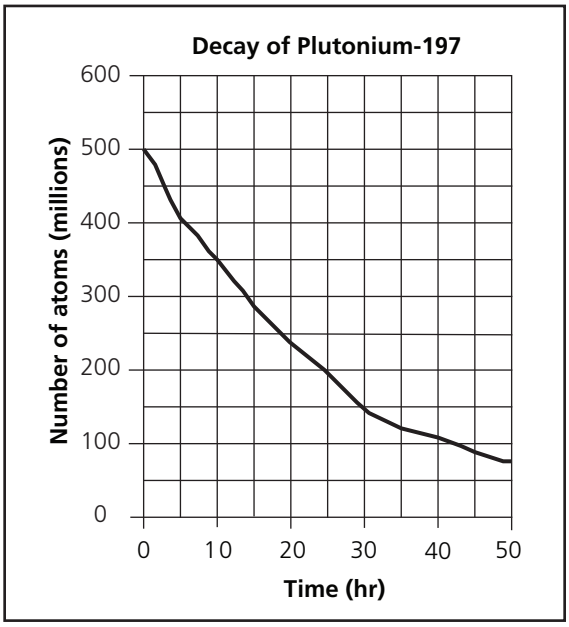
1. Rhenium (Re)-184 has a half-life of 38 d. A sample containing Re-184 has an activity of 1296 Bq.
   (a) What will the activity of the sample be in 152 days?

   (b) What was the activity of the sample 190 days ago?

   (c) After how many days will the activity level of the sample be 324 Bq?

2. The graph below shows the decay of a sample of platinum (Pt)-197.
   (a) What is the half-life of Pt-197?

   (b) Approximately how many atoms of Pt-197 will remain after 72 hours?



Name: _____ Date: _____ 10.4

TechConnect: Brachytherapy

Read the TechConnect feature on page 297, and answer the following questions. Explain on the lines provided why you chose each answer.

1. Why is brachytherapy considered an improvement over many other kinds of radiation therapy for cancer?

   A. It does not produce any harmful side-effects.
   B. It is less expensive than other forms of radiation treatment.
   C. It allows radiation to be concentrated at the site of a tumour.
   D. It can be used to treat more forms of cancer than other types of radiation therapy.

   Why? _____

   _____

   _____

2. In brachytherapy, "seeds" of a radioactive isotope are implanted in the body. Which of the following is the most likely the half-life of the isotope?

   A. 2.3 days
   B. 12 months
   C. 10 seconds
   D. 0.3 microseconds

   Why? _____

   _____

   _____

3. An isotope with which of these half-lives would most likely be used with a remote afterloader?

   A. 2 seconds
   B. 4 minutes
   C. 6 hours
   D. 10 days

   Why? _____

   _____

4. Figure 1 indicates that iodine "seeds" implanted in the prostate gland should not be too close to the urethra. What is the most likely explanation?

   A. The seeds could rupture in the non-target tissue.
   B. The radiation could damage tissues of the urethra.
   C. The urethra could block the effects of the radiation.
   D. The cancerous prostate cells could migrate to the urethra.

   Why? _____

   _____

Name: _____ Date: _____

CHAPTER 10

Matching Challenge: Radioactivity

Match each word or phrase on the left with the phrase on the right that best describes it.

_____ alpha particle	(a) an electron
_____ atomic mass	(b) isotopes of an element have different numbers of these
_____ beta particle	(c) a form of radiation with no charge, no mass, and the highest energy of all forms of radiation
_____ daughter nucleus	(d) the central part of an atom
_____ decay	(e) for a sample containing 100 radioactive atoms, this is the time required for 50 of them to decay
_____ gamma ray	(f) high-energy particles or waves given off when a nucleus decays
_____ half-life	(g) the release of energy and, sometimes, particles from a nucleus
_____ mass number	(h) the number of protons in an atom of an element
_____ neutrons	(i) a nucleus that can break down to form a nucleus of a new element
_____ nucleus	(j) a helium nucleus
_____ parent nucleus	(k) the sum of the number of protons and neutrons in a nucleus
_____ radiation	(l) a nucleus produced when another nucleus decays

Name: _____ Date: _____

CHAPTER 10

Chapter Checklist

Learning Outcome/Achievement Indicator	I feel confident that I have achieved this outcome.		BC Science Probe 10 Reference for Review
	Yes ✓	No ✓	
• explain radioactivity using modern atomic theory Notes:			Section 10.1, pp. 274–279 Section 10.2, pp. 280–283 Section 10.3, pp. 284–289 Section 10.4, pp. 290–296
• define isotope in terms of atomic number and mass number, recognizing how these are communicated in standard atomic notation (e.g. Uranium-238: $^{238}_{92}U$ Notes:			Section 10.2, pp. 280–283
• relate radioactive decay (e.g., alpha – α, beta – β, gamma – γ) to changes in the nucleus Notes:			Section 10.3, pp. 284–289
• relate the following subatomic particles to radioactive decay: – proton (^1_1p) – neutron (^1_0n) – electron ($^0_{-1}e$) – alpha particle ($^4_2\alpha$) ($^4_2$He) – beta particle ($^0_{-1}\beta$) Notes:			Section 10.3, pp. 280–283
• explain half-life with reference to rates of radioactive decay Notes:			Section 10.4, pp. 290–296
• complete and balance nuclear equations to illustrate radioactive decay Notes:			Section 10.3, pp. 284–289

Name: _____ Date: _____

Unit C

Worksheet: Test-Taking Strategies

- Good test-takers adjust their reading to fit the difficulty of the test item. If you find a test item that is difficult to understand, read more slowly or read it more than once.
- If the item includes a graph or diagram, study that first, and then read the question.
- Skim the question, relate what the question asks for to the graph or diagram, and try to figure out the correct answer before you read the answer choices.

Sample Item

Scientists in British Columbia collected a large amount of data on a new radioactive isotope that has just been discovered. The scientists used their data to produce a graph of the activity levels of the sample (Figure 1).

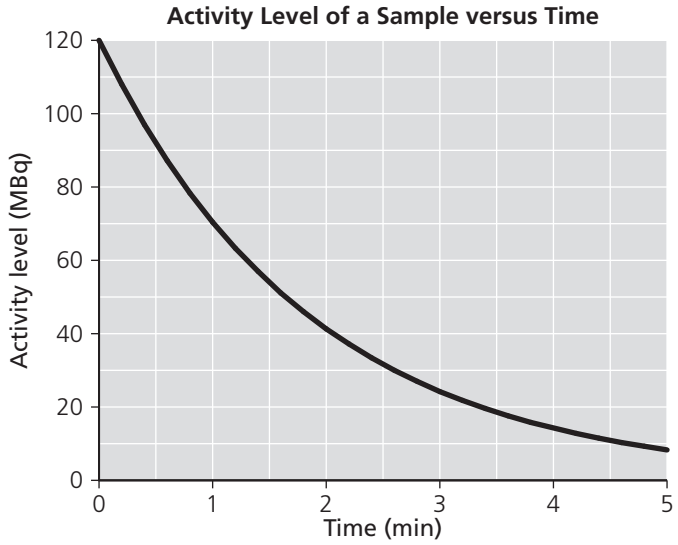


Figure 1

Based on the Figure 1, which of the following should the scientists determine is the half-life of the sample?

A. 1.0 min
B. 1.3 min
C. 2.5 min
D. 5.0 min

Worksheet: Test-Taking Strategies (continued)

Description/Discussion of Strategies

Multiple choice test questions are often written as three parts: the *stem,* the *diagram,* and the *answer choices.* The stem includes all the text you have to read except the answer choices themselves. In many cases, the stem of a test item includes information that is not directly related to answering the question. This information can make the test item seem confusing.

To succeed in answering an item like the one shown, first skim the item stem. If the stem is wordy or difficult to understand, slow your reading pace and reread. After reading the stem carefully, you may find that the question is easier than you think. After reading the stem, look carefully at the diagram shown. This diagram is a graph, so the answer choices will all relate to the information shown on the graph.

Some questions will ask you to simply provide the correct answer based solely on the information given in the diagram. Other questions, such as this one, ask that you use your own knowledge as well to answer the question. Based on your prior knowledge and the stem, you should be able to figure out the correct answer. Once you've determined the correct answer, look for it among the answer choices.

Practice Item

In the Figure 2, the particle given off consists of 2 protons and 2 neutrons. Which process does this show?

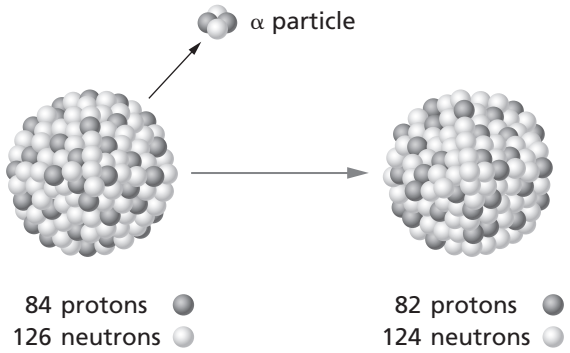


Figure 2

A. alpha decay
B. beta decay
C. gamma decay
D. quanta decay

Name: _____ Date: _____

CHAPTER 10

Chapter 10 Quiz

Part A: Modified True/False
Indicate whether each statement is true or false. If the statement is false, change the underlined word or phrase to make the statement true.

____ 1. Radiation is defined as the spontaneous emission of radiation from the <u>nucleus</u> of an atom. _____

____ 2. Isotopes of the same element have different <u>chemical properties</u>. _____

____ 3. When an atom emits an alpha particle, its mass number decreases by <u>2</u> atomic mass units. _____

Part B: Completion
Complete the following sentences.

4. Cathode rays are made of particles that are now known as _____ .

5. An atom of lead (Pb)-204 has _____ neutrons.

6. Gamma decay can occur when a nucleus is in a(n) _____ state.

Part C: Matching
Match each form of radiation to its description. then put the forms of radiation in order of their penetrating ability, from least penetrating to most penetrating.

____ 7. alpha particle	(a) electron
____ 8. beta article	(b) electromagnetic radiation
____ 9. gamma ray	(c) helium nucleus

Part D: Multiple Choice
Circle the letter beside the answer that best completes the statement or answers the question.

10. What does the amount of radiation given off by a sample of uranium depend on?
    A. the amount of uranium in the sample
    B. the temperature of the uranium sample
    C. the amount of pressure applied to the uranium sample
    D. the particular uranium compounds that exist in the sample

11. Which best describes gamma decay?
    A. emission of a proton
    B. emission of an electron
    C. emission of a helium nucleus
    D. emission of electromagnetic radiation

Chapter 10 Quiz (continued)

12. In a cloud chamber, gamma rays produce no track because they have no
    A. mass
    B. charge
    C. energy
    D. movement

13. The probability that any individual atom of a radioactive isotope will decay
    A. decreases over time
    B. increases over time
    C. fluctuates over time
    D. stays the same over time

14. Half-life is the same for
    A. all atoms of the same isotope
    B. all atoms of the same element
    C. all atoms of all radioactive isotopes
    D. all atoms of the same atomic mass

15. Uranium-235 has a half-life of about 700 million years. After how many years will only 25 % of the parent nuclei remain?
    A. 70 million years
    B. 350 million years
    C. 1400 million years
    D. 2100 million years

16. Which equation shows a correct representation of beta decay?
    A. $^{232}_{90}\text{Th} \longrightarrow {}^{228}_{88}\text{Ra} + {}^{4}_{2}\text{He}$
    B. $^{239}_{93}\text{Np} \longrightarrow {}^{239}_{94}\text{Pu} + {}^{0}_{-1}\text{e}$
    C. $^{221}_{87}\text{Fr} \longrightarrow {}^{225}_{89}\text{Ac} + {}^{4}_{2}\text{He}$
    D. $^{19}_{8}\text{O} \longrightarrow {}^{19}_{7}\text{N} + {}^{0}_{-1}\text{e}$

17. A sample of material contains 6 000 radioactive atoms of a particular parent isotope. How many atoms of the parent isotope will remain in the sample after three half-lives?
    A. 300
    B. 750
    C. 1 800
    D. 2 000

Part E: Short Answer

18. During beta decay, the nucleus of the atom emits an electron.
    (a) Based on your knowledge of the structure of an atom's nucleus, explain why this seems counterintuitive.

    _____

    _____

    (b) Explain how it is possible.

    _____

    _____

19. Write the equation for the beta decay of tin-121