

Snow Day
Physics PRICE

Chapter 22 Section 1 The Nucleus

Preview

- Objectives
- Properties of the Nucleus
- Nuclear Stability
- Binding Energy
- Sample Problem

Chapter 22 Section 1 The Nucleus

Objectives

- Identify the properties of the nucleus of an atom.
- Explain why some nuclei are unstable.
- Calculate the binding energy of various nuclei.

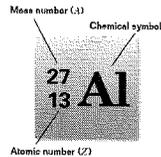


Chapter 22 Section 1 The Nucleus

Properties of the Nucleus

Nuclear Quantities

- The **mass number (A)** represents the total number of protons and neutrons—or nucleons—in the nucleus.
- The **atomic number (Z)** represents the number of protons in the nucleus.
- The **neutron number (N)** represents the number of neutrons in the nucleus.



The chemical symbol of an element is often written with its mass number and atomic number.



Chapter 22 Section 1 The Nucleus

Properties of the Nucleus, continued

Isotopes

- Although **atomic number** does not change within an element, atoms of the same element can have different **mass numbers**. This is because the **number of neutrons** in a particular element can vary.
- Atoms that have the **same atomic number** but **different neutron numbers** (and thus different mass numbers) are called **isotopes**.



Chapter 22 Section 1 The Nucleus

Isotopes

Click below to watch the Visual Concept.

Visual Concept

Chapter 22 Section 1 The Nucleus

Properties of the Nucleus, continued

The Unified Mass Unit

- Because the mass of a nucleus is extremely small, the **unified mass unit, u** , is often used for atomic masses. This unit is sometimes referred to as the **atomic mass unit**.
- $1 u$ is defined so that **$12 u$** is equal to the mass of **one atom of carbon-12**.
- The proton and neutron each have a mass of about $1 u$.



Chapter 22 Section 1 The Nucleus

Properties of the Nucleus, *continued*

Rest Energy

- A particle has a certain amount of energy, called **rest energy**, associated with its mass.
- The following equation expresses the relationship between mass and rest energy mathematically:

$$E_R = mc^2$$

rest energy = (mass)(speed of light)²



Chapter 22 Section 1 The Nucleus

Nuclear Stability

- There must be an **attractive force** to overcome the Coulomb repulsion between protons in the nucleus.
- This force is called the **strong force**.
 - The strong force is almost completely **independent of electric charge**. For a given separation, the force of attraction between two protons, two neutrons, or a proton and a neutron has the same magnitude.
 - Another unusual property of the strong force is its **very short range**, only about 10^{-15} m.



Chapter 22 Section 1 The Nucleus

Nuclear Stability, *continued*

- Heavy nuclei are stable only when they have **more neutrons than protons**.
- This can be understood in terms of the **strong force**.
 - For a nucleus to be stable, the repulsion between positively-charged protons must be balanced by the strong nuclear force's attraction between all the particles in the nucleus.
 - The repulsive force exists between all protons in a nucleus. But a proton or a neutron attracts only its nearest neighbors.
 - So, as the number of protons increases, the number of neutrons has to increase even more to add enough attractive forces to maintain stability.



Chapter 22 Section 1 The Nucleus

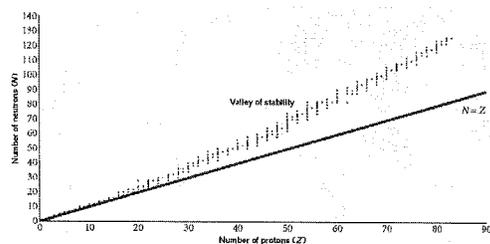
Nuclear Stability, *continued*

- For **Z greater than 83**, the repulsive forces between protons cannot be compensated by the addition of more neutrons.
- That is, **elements that contain more than 83 protons do not have stable nuclei**.
 - The long, narrow region in the graph of *N* vs. *Z* (on the next slide) is sometimes referred to as the **valley of stability**.
 - Nuclei that are not stable decay into other nuclei until the decay product is one of the nuclei located in the valley of stability.



Chapter 22 Section 1 The Nucleus

Number of Protons Versus Number of Neutrons for Stable Nuclei



Chapter 22 Section 1 The Nucleus

Nuclear Stability and the Ratio of Neutrons and Protons

Click below to watch the Visual Concept.



Chapter 22 Section 1 The Nucleus

Binding Energy

- A **stable nucleus's** mass is **less** than the masses of its **nucleons**. The mass of the nucleons when unbound minus the mass of the nucleons when bound is called the **mass defect**.
- The **binding energy** is the energy released when unbound nucleons come together to form a stable nucleus, which is equivalent to the energy required to break the nucleus into individual nucleons.

$$E_{bind} = \Delta mc^2$$

binding energy = mass defect \times (speed of light)²



Chapter 22 Section 1 The Nucleus

Binding Energy, *continued*

- The **mass defect** can also be expressed as follows:

$$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass}$$
- Use this equation and the **atomic masses** given in **Appendix H** of the textbook to calculate mass defect when solving problems involving binding energy.
- The **binding energy per nucleon** for light nuclei ($A < 20$) is much smaller than the binding energy per nucleon for heavier nuclei.
- In other words, particles in lighter nuclei are less tightly bound on average than particles in heavier nuclei.



Chapter 22 Section 1 The Nucleus

Sample Problem

Binding Energy

The nucleus of the deuterium atom, called the deuteron, consists of a proton and a neutron. Given that the atomic mass of deuterium is 2.014 102 u, calculate the deuteron's binding energy in MeV.



Chapter 22 Section 1 The Nucleus

Sample Problem, *continued*

1. Define

Given:

$$Z = 1$$

$$N = 1$$

$$\text{atomic mass of deuterium} = 2.014\ 102\ \text{u}$$

$$\text{atomic mass of H} = 1.007\ 825\ \text{u}$$

$$m_n = 1.008\ 665\ \text{u}$$

Unknown:

$$E_{bind} = ?$$



Chapter 22 Section 1 The Nucleus

Sample Problem, *continued*

2. Plan

Choose an equation or situation:

First, find the mass defect with the following relationship:

$$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass}$$

Then, find the binding energy by converting the mass defect to rest energy.



Chapter 22 Section 1 The Nucleus

Sample Problem, *continued*

3. Calculate

Substitute the values into the equation and solve: --

$$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass}$$

$$\Delta m = 1(1.007\ 825\ \text{u}) + 1(1.008\ 665\ \text{u}) - 2.014\ 102\ \text{u}$$

$$\Delta m = 0.002\ 388\ \text{u}$$

$$E_{bind} = (0.002\ 388\ \text{u})(931.49\ \text{MeV/u})$$

$$E_{bind} = 2.224\ \text{MeV}$$

4. Evaluate

In order for a deuteron to be separated into its constituents (a proton and a neutron), 2.224 MeV of energy must be added.



Chapter 22 Section 2 Nuclear Decay

Preview

- [Objectives](#)
- [Nuclear Decay Modes](#)
- [Nuclear Decay Series](#)
- [Sample Problem](#)
- [Measuring Nuclear Decay](#)

Chapter 22 Section 2 Nuclear Decay

Objectives

- **Describe** the three modes of nuclear decay.
- **Predict** the products of nuclear decay.
- **Calculate** the decay constant and the half-life of a radioactive substance.



Chapter 22 Section 2 Nuclear Decay

Nuclear Decay Modes

- The nuclear decay process can be a natural event or can be induced artificially. In either case, when a nucleus decays, **radiation** is emitted in the form of **particles, photons, or both**.
- The nucleus before decay is called the **parent nucleus**, and the nucleus remaining after decay is called the **daughter nucleus**.
- In all nuclear reactions, the **energy released** is found by the equation $E = \Delta mc^2$.



Chapter 22 Section 2 Nuclear Decay

Nuclear Decay Modes, continued

Three types of radiation can be emitted by a nucleus as it undergoes radioactive decay:

- **alpha (α) particles**, which are ^4_2He nuclei
- **beta (β) particles**, which are either electrons or positrons (positively charged particles with a mass equal to that of the electron)
- **gamma (γ) rays**, which are high-energy photons



Chapter 22 Section 2 Nuclear Decay

Alpha, Beta, and Gamma Radiation

Particle	Symbols	Composition	Charge	Effect on parent nucleus
alpha	α (^4_2He)	2 protons, 2 neutrons	+2	mass loss; new element produced
beta	β^- ($^0_{-1}e$)	electron	-1	no change in mass number; new element produced
	β^+ ($^0_{+1}e$)	positron	+1	
gamma	γ	photon	0	energy loss

Chapter 22 Section 2 Nuclear Decay

Nuclear Decay Modes, continued

Two rules can be used to determine the unknown daughter atom when a parent atom undergoes decay:

- The total of the **atomic numbers** on the left is the same as the total on the right because **charge must be conserved**.
- The total of the **mass numbers** on the left is the same as the total on the right because **nucleon number must be conserved**.



Chapter 22 Section 2 Nuclear Decay

Alpha, Beta, and Gamma Radiation

Click below to watch the Visual Concept.



Chapter 22 Section 2 Nuclear Decay

Nuclear Decay Modes, *continued*

- Beta decay transforms **neutrons** and **protons** in the nucleus:
- In beta decay, an **electron** is always accompanied by an **antineutrino** and a **positron** is always accompanied by a **neutrino**.
 - A **neutrino** is a particle with zero electric charge and a very small mass (much smaller than the mass of the electron).
 - An **antineutrino** is the antiparticle of a neutrino.



Chapter 22 Section 2 Nuclear Decay

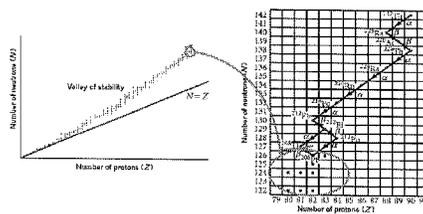
Nuclear Decay Series

- If the product of a nuclear decay is **stable**, the decay process ends.
- In other cases, the decay product—the daughter nucleus—is itself **unstable**. The daughter nucleus then becomes the parent nucleus for an additional decay process.
- Such a sequence is called a **decay series**.
- The next slide shows a decay series that begins with thorium, Th, and ends with lead, Pb.



Chapter 22 Section 2 Nuclear Decay

Nuclear Stability and Nuclear Decay



The black dots represent stable nuclei, and the red dots represent unstable nuclei. Each black dot on the right corresponds to a data point in the circled portion on the left.

Chapter 22 Section 2 Nuclear Decay

Sample Problem

Nuclear Decay

The element radium was discovered by Marie and Pierre Curie in 1898. One of the isotopes of radium, Ra, decays by alpha emission. What is the resulting daughter element?

Given:

Unknown: the daughter element (X)



Chapter 22 Section 2 Nuclear Decay

Sample Problem, *continued*

The mass numbers and atomic numbers on the two sides of the expression must be the same so that both charge and nucleon number are conserved during the course of this particular decay.

$$\text{Mass number of X} = 226 - 4 = 222$$

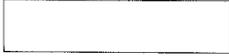
$$\text{Atomic number of X} = 88 - 2 = 86$$



Chapter 22 Section 2 Nuclear Decay

Sample Problem, *continued*

The periodic table (Appendix G in the textbook) shows that the nucleus with an atomic number of 86 is radon, Rn. Thus, the decay process is as follows:



Chapter 22 Section 2 Nuclear Decay

Measuring Nuclear Decay

Decay Constant

- If a sample contains N radioactive parent nuclei at some instant, the number of parent nuclei that decay into daughter nuclei (ΔN) in a small time interval (Δt) is proportional to N :

$$\Delta N = -\lambda \Delta t$$

- The negative sign shows that N decreases with time.
- The quantity λ is called the **decay constant**. The value of λ for any isotope indicates the rate at which that isotope decays.



Chapter 22 Section 2 Nuclear Decay

Measuring Nuclear Decay, *continued*

Activity

- The number of decays per unit time, $-\Delta N/\Delta t$, is called the **decay rate**, or **activity**, of the sample.
- Activity equals the decay constant times the number of radioactive nuclei in the sample:

- The SI unit of activity is the **becquerel (Bq)**. One becquerel is equal to 1 decay/s.



Chapter 22 Section 2 Nuclear Decay

Measuring Nuclear Decay, *continued*

Half-Life

- Another quantity that is useful for characterizing radioactive decay is the **half-life**, written as $T_{1/2}$.
- The **half-life** of a radioactive substance is the time needed for half of the original nuclei of a sample of a radioactive substance to undergo radioactive decay.
- The **half-life** of any substance is **inversely proportional** to the substance's **decay constant**.



Chapter 22 Section 2 Nuclear Decay

Half-Life

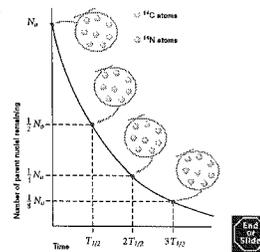
Click below to watch the Visual Concept.



Chapter 22 Section 2 Nuclear Decay

Measuring Nuclear Decay, *continued*

- A typical **decay curve** for a radioactive sample is shown in the diagram.
- The **blue spheres** are the **parent nuclei** (carbon-14), and the **red spheres** are **daughter nuclei** (nitrogen-14).
- The total number of nuclei remains **constant**, while the number of carbon atoms continually decreases.



Chapter 22 Section 3 Nuclear Reactions

Preview

- Objectives
- Fission
- Fusion



Chapter 22 Section 3 Nuclear Reactions

Objectives

- Distinguish between nuclear fission and nuclear fusion.
- Explain how a chain reaction is utilized by nuclear reactors.
- Compare fission and fusion reactors.



Chapter 22 Section 3 Nuclear Reactions

Fission

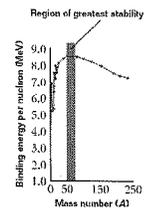
- Any process that involves a change in the nucleus of an atom is called a **nuclear reaction**.
- Nuclear **fission** occurs when a heavy nucleus splits into two lighter nuclei.
- For fission to occur naturally, the nucleus must release energy. This means that the **nucleons in the daughter nuclei must be more tightly bound** and therefore have **less mass** than the nucleons in the parent nucleus.



Chapter 22 Section 3 Nuclear Reactions

Fission, continued

- Because fission produces lighter nuclei, the binding energy per nucleon must increase with decreasing atomic number.
- The figure shows that this is possible only for atoms in which $A > 58$.
- Thus, *fission occurs naturally only for heavy atoms*.



Chapter 22 Section 3 Nuclear Reactions

Fission, continued

- The **energy released** in a fission event is **very large** relative to the energy released in typical chemical reactions.
- For example, the energy released in burning one molecule of the octane used in gasoline engines is about **one hundred-millionth** the energy released in a **single fission event**.



Chapter 22 Section 3 Nuclear Reactions

Fission, continued

An estimate for the energy released in a typical fission process is as follows:

- The binding energy per nucleon is about 7.6 MeV for heavy nuclei and about 8.5 MeV for intermediate nuclei.
- The amount of energy released in a fission event is the difference in these binding energies (8.5 MeV - 7.6 MeV, or about 0.9 MeV per nucleon).
- Assuming a total of 240 nucleons, this is about 220 MeV.



Chapter 22 Section 3 Nuclear Reactions

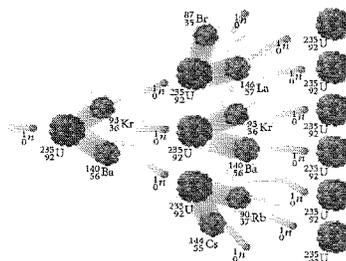
Fission, *continued*

- The neutrons released in a fission event can be captured by other nuclei, making these nuclei unstable.
- This triggers additional fission events, which lead to the possibility of a **chain reaction**.
- If the chain reaction does not proceed slowly, it could result in the release of an enormous amount of energy and a violent explosion.



Chapter 22 Section 3 Nuclear Reactions

A Nuclear Chain Reaction



Chapter 22 Section 3 Nuclear Reactions

Fission, *continued*

- A **nuclear reactor** is a system designed to maintain a controlled, self-sustained chain reaction.
- At this time, **all nuclear reactors operate through fission**.
 - One difficulty associated with fission reactors is the safe disposal of radioactive materials when the core is replaced. Transportation of reactor fuel and reactor wastes poses safety risks.
 - As with all energy sources, the risks must be weighed against the benefits and the availability of the energy source.



Chapter 22 Section 3 Nuclear Reactions

Nuclear Fission

Click below to watch the Visual Concept.



Chapter 22 Section 3 Nuclear Reactions

Fusion

- Nuclear **fusion** occurs when two light nuclei combine to form a heavier nucleus.
- As with fission, the product of a fusion event must have a **greater binding energy** than the original nuclei for energy to be released in the reaction.
- Because fusion reactions produce heavier nuclei, the binding energy per nucleon must increase as atomic number increases. This is possible only for atoms in which $A < 58$.
- Thus, *fusion occurs naturally only for light atoms*.



Chapter 22 Section 3 Nuclear Reactions

Fusion, *continued*

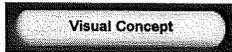
- All **stars** generate energy through fusion.
- Efforts are under way to create controlled thermonuclear reactions in the form of a **fusion reactor**.
- There are several **advantages** to nuclear fusion:
 - The fuel costs are insignificant.
 - Few radioactive byproducts are formed.
- However, the high temperatures required are difficult and expensive to obtain in a laboratory or power plant.



Chapter 22 Section 3 Nuclear Reactions

Nuclear Fusion

Click below to watch the Visual Concept.



Chapter 22 Section 4 Particle Physics

Preview

- Objectives
- [The Particle View of Nature](#)
- [Classification of Particles](#)
- [The Standard Model](#)



Chapter 22 Section 4 Particle Physics

Objectives ▾

- Define the four fundamental interactions of nature. ▾
- Identify the elementary particles that make up matter. ▾
- Describe the standard model of the universe.



Chapter 22 Section 4 Particle Physics

The Particle View of Nature ▾

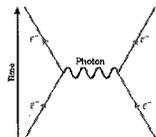
- Until 1932, scientists thought **protons** and **electrons** were elementary particles. ▾
- However, beginning in 1945, experiments at particle accelerators have demonstrated that **new particles** are often formed in **high-energy collisions between known particles**. ▾
 - These new particles tend to be **very unstable** and have **very short half-lives**. ▾
 - More than **300 new particles** have been catalogued.



Chapter 22 Section 4 Particle Physics

The Particle View of Nature, *continued* ▾

- In particle physics, the **interaction** of matter is usually described not in terms of forces but in terms of the **exchange of special particles**. ▾
- The diagram shows how two electrons might repel each other through the exchange of a photon. ▾
- Because momentum is conserved, the two electrons change direction and move away from each other.



Chapter 22 Section 4 Particle Physics

The Particle View of Nature, *continued* ▾

- All particles in nature are subject to **four fundamental interactions**:
 - Strong
 - Electromagnetic
 - Weak
 - Gravitational ▾
- Each interaction has its own **mediating field particle**.



The Fundamental Interactions of Nature

Interaction (force)	Relative strength	Range of force	Mediating field particle
strong	1	≈ 1 fm	gluon
electromagnetic	10^{-2}	proportional to $1/r^2$	photon
weak	10^{-13}	$< 10^{-3}$ fm	W^\pm and Z bosons
gravitational	10^{-38}	proportional to $1/r^2$	graviton

Forces in Atoms

Click below to watch the Visual Concept.



Classification of Particles

- All particles other than the mediating field particles can be classified into two broad categories:
 - Leptons
 - Hadrons
- Leptons do not participate in the the strong interaction, but hadrons do.



Classification of Particles, continued

Leptons

- Leptons have no internal structure and do not seem to break down into smaller units.
- Thus, leptons appear to be truly elementary.
- Currently, scientists believe there are only six leptons: the electron, the muon, the tau, and a neutrino associated with each.
- Each of these six leptons also has an antiparticle.



Classification of Particles, continued

Hadrons

Hadrons can be further divided into two classes: mesons and baryons.

- All mesons are unstable. Because of this, they are not constituents of normal, everyday matter.
- The most common examples of baryons are protons and neutrons, which are constituents of normal, everyday matter.



Classification of Particles, continued

Hadrons

- All hadrons are composed of two or three fundamental particles, which are called quarks.
- The difference between mesons and baryons is due to the number of quarks that compose them.
- All quarks have a charge associated with them. The charge of a hadron is equal to the sum of the charges of its constituent quarks.



Quarks and their Charges

Click below to watch the Visual Concept.



The Standard Model

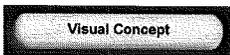
The current model used in particle physics to understand matter is called the **standard model**.

- According to the standard model, the **strong force** is mediated by **gluons**. This force holds quarks together to form composite particles, such as protons, neutrons, and mesons.
- **Leptons** participate only in the electromagnetic, gravitational, and weak interactions.
- The **combination of composite particles**, such as protons and neutrons, with **leptons**, such as electrons, makes the constituents of all matter, which are **atoms**.



The Standard Model of Particle Physics

Click below to watch the Visual Concept.



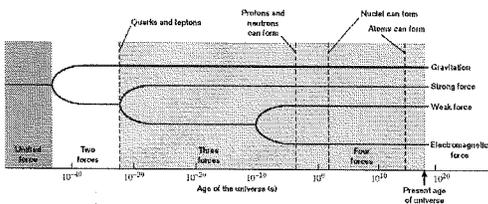
The Standard Model, *continued*

The standard model helps explain the early universe.

- About 15 billion to 20 billion years ago, the universe was inconceivably small. In the brief instant after this singular moment, the universe expanded rapidly in an event called the **big bang**.
- Immediately afterward, there were such extremes in the density of matter and energy that **all four interactions operated in a single, unified way**.
- The **evolution** of the four fundamental interactions from the big bang to the present is shown on the next slide.



The Evolution of the Universe from the Big Bang



The Standard Model, *continued*

- Particle physics still faces many questions, such as:
 - Why do quarks and leptons form three similar but distinct families?
 - Why are some particles charged and others neutral?
 - Why do quarks carry a fractional charge?
 - Can isolated quarks exist?
- Because of the rapid advances and new discoveries in the field of particle physics, by the time you read this textbook, some of these questions may have been resolved, while new questions may have emerged.



GLOSSARY

● B

band gap the minimum energy separation between the highest occupied state and the lowest empty state (868)

● D

diode an electronic device that allows electric current to pass more easily in one direction than in the other (874)

doping the addition of impurity atoms to a semiconductor (873)

● E

excited state the state of an atom that is no longer in its ground state (867)

● G

ground state the lowest-energy state of a quantized system (867)

● H

hole an energy level that is not occupied by an electron in a semiconductor (872)

● T

transistor a device, typically containing three terminals, that can amplify a signal (877)

● V

valence electron an electron in the outermost shell of an atom (867)

READING SKILLS

Day 1 Physics

● **K-W-L**

I Know

I Want to know

I Learned

TOPIC: Nuclear Physics

List what you already know about the topic you identified above.

What do I know now?

List what you wonder about or want to know about the topic.

What do I want to know?

Finally, list what you learned about the topic.

What did I learn?

Section
25-1

HOLT PHYSICS

Concept Review

Day 2 Physics

The Nucleus

1. A certain atom has eight protons, eight electrons, and eight neutrons.

a. How many nucleons does this atom have?

b. What is the atomic number of this atom?

c. What is the mass number of this atom?

d. If the nucleus of this atom has a mass of 16.124 552 u, calculate the binding energy of the nucleus.

e. What is the significance of the binding energy?

f. Would an atom with eight protons, eight electrons, and nine neutrons be a different element? Explain.

2. Two protons in a nucleus experience a very large repulsion force.

a. What prevents these two protons from accelerating away from each other?

b. As a nucleus gets larger, what happens to the ratio of protons to neutrons?

HRW material copyrighted under notice appearing earlier in this book.

Section
25-2

HOLT PHYSICS

Concept Review

Day 3 Physics

Nuclear Decay

1. List and describe the three types of radiation emitted by radioactive materials.

2. Find the element produced in the following decays:

a. Nitrogen-17 decays by emitting a beta particle. _____

b. Uranium-235 decays by emitting an alpha particle. _____

c. Uranium-238 decays by emitting a beta particle. _____

d. Plutonium-239 decays by emitting an alpha particle. _____

3. What does the term *half-life* mean?

4. What is the decay constant?

5. What is the mathematical relationship between the decay constant and the half-life of a substance?

6. Find the decay constant of a material that has a half-life of 14 s.

7. Find the half-life of a material that has a decay constant of $2.20 \times 10^{-8} \text{ s}^{-1}$.

8. How much of the material in item 7 will remain after two years?

HRW material copyrighted under notice appearing earlier in this book.

Section
25-3

HOLT PHYSICS

Concept Review

Day 4 Physics

Nuclear Reactions

1. A typical nuclear reaction is ${}_0^1\text{n} + {}_{92}^{235}\text{U} \rightarrow {}_{56}^{141}\text{Ba} + {}_{36}^{92}\text{Kr} + 3 {}_0^1\text{n}$.

a. Is this a fission reaction or a fusion reaction?

b. What are the reactants in this reaction?

c. What are the products of this reaction?

d. Are mass and charge conserved in this reaction?

e. This reaction produces three neutrons. What might happen if each neutron is absorbed by another uranium nucleus?

f. What is the danger of an uncontrolled nuclear reaction?

2. Another possible reaction is ${}_1^1\text{H} + {}_2^3\text{He} \rightarrow {}_2^4\text{He} + {}_1^0\text{e} + \nu$.

a. Is this a fission reaction or a fusion reaction?

b. What are the reactants in this reaction?

c. What are the products of this reaction?

d. Are mass and charge conserved in this reaction?

HRW material copyrighted under notice appearing earlier in this book.

Section
25-4

HOLT PHYSICS

Concept Review

Day 5 Physics

Particle Physics

- 1.** List the four fundamental interactions in order of relative strength. Describe each interaction, including relative strength, effects, and the range of force.

- 2.** The four fundamental interactions each have a mediating particle.

- a.** List the mediating particles for each of the following types of interactions:

gravitational _____

weak _____

electromagnetic _____

strong _____

- b.** Which mediating particle has not yet been discovered?

- 3.** The standard model proposes the existence of a particle called the Higgs boson.

- a.** What is the reason scientists predict the existence of the Higgs boson?

- b.** Why has this particle not been observed?

CONNECTION TO LANGUAGE ARTS

Day 6 Physics

• Marie Curie and the Naming of a Unit

Maria Sklodowska was born in Warsaw, Poland, in 1867. Maria completed her secondary education with honors when she was only 16 years old. When her father lost his savings, Maria worked as a teacher and a governess to finance her sister's medical education in Paris.

When she was 24 years old, Maria went to the university in Paris. Because she had little money, she survived almost exclusively on a diet of bread, butter, and tea. After 2 years, she finished first in physical science. The next year, she finished second in mathematics.

Marie Curie's Career in Science

In 1894, Maria met Pierre Curie, another scientist. When the two were married, Maria Sklodowska became known as Marie Curie. Working together, Pierre and Marie discovered both polonium, named by Marie for her homeland, and radium.

Marie did research to find out if a special property of uranium was present in other elements. She identified this special property in thorium, and she called the property *radioactivity*. She received her doctorate in 1903. That same year, she shared the Nobel prize in physics with her husband and Henri Becquerel for the discovery of radioactivity.

A Second Nobel Prize

Pierre died in an accident in 1906. Marie continued her work and received the 1911 Nobel prize in chemistry for isolating pure radium. Marie's daughter, Irene, and her husband, Frederic Joliot, were awarded the Nobel prize in chemistry in 1935 for research in artificial radioactivity.

Marie Curie has been honored by having the *curie*, a unit of radioactivity, named after her. One curie equals 3.7×10^{10} disintegrations per second.

Your Turn to Think

1. What are the two elements that Marie and Pierre discovered?
2. What is a curie?
3. What jobs did Marie Curie hold before she went to the university?
4. Was Marie Curie's career typical for women of her time? Explain.

CONNECTION TO SOCIAL STUDIES

Day 7 Physics

● Alchemists' Theory of the Elements

In the Middle Ages, alchemists, who practiced philosophy and primitive science, believed that all matter was made from some combination of the four elements—earth, air, fire, and water. They were convinced that they could change one substance into another by changing the balance of its elements. They were encouraged by observing that when water evaporated, a bit of sediment always remained. They concluded that water had been changed to earth.

Your Turn to Think

Today scientists know that for one substance to become another, a chemical reaction must take place. Key evidence of a chemical reaction includes a change in properties, a change in color, and the release or absorption of energy. Keep these facts in mind as you analyze the following experiment.

Martel, an alchemist in the Middle Ages, fills a shallow bowl with sea water and sets it in an open, sunlit window. In time, the water disappears but the bottom and sides of the bowl are coated with a white powdery substance.

1. Alchemists had to rely primarily on their senses to analyze substances. How could Martel quickly test the powdery substance in the bowl to determine if it had properties similar to those of the original seawater? What would he discover?
2. Martel decided to try his experiment again using water from a muddy river. What might he discover about color change when the water evaporated?
3. Did Martel's experiments produce a chemical reaction? What is your evidence?

Day 7 physics

CONNECTION TO SOCIAL STUDIES

● **Fireworks**

The Importance of Black Powder

Although no one really knows when pyrotechnics—fireworks—were first used, most people credit the Chinese with the invention. The key to fire-works is black powder, which gives firecrackers their bang and gives skyrockets their flight. Today’s preparation for making black powder differs little from the one used in first- or second-century China.

Through the years, pyrotechnicians experimented to improve on the visual display of fireworks. They discovered that packing certain chemical compounds with the black powder could create colored flames, sparks, and smokes. In some fireworks, black powder is used with additional ingredients that produce various types of sparks. In other fireworks, such as the stars that are shot out of rockets, potassium nitrate, salts of antimony, and sulfur may be used. For colored fire, potassium chlorates are combined with a metal salt that provides the color. The table at right lists some elements and the colors that they produce.

Elements Used in Many Fireworks

Element	Symbol	Color or Effect
Copper	Cu	Blue
Sodium	Na	Yellow
Lithium	Li	Red
Strontium	Sr	Red
Barium	Ba	Green
Magnesium	Mg	Bright white flames
Aluminum	Al	Silver and white sparks
Zinc	Zn	Thick smoke clouds
Antimony	Sb	Glitter effects

How Aerial Stars Are Made

Some of the most popular fireworks used today are aerial stars. Stars are made from carefully prepared chemicals that are packaged with black powder in cardboard compartments, called breaks, within the large overall shell of the firework. A time-delay fuse is used to ignite the stars when they are high in the air. As the firework zooms through the air, the time-delay fuse burns. When the fuse reaches the black powder in the break, the stars ignite. Some fireworks carry two or three breaks.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CONNECTION TO SOCIAL STUDIES

● **Fireworks** *continued*

Your Turn to Think

1. What chemicals would create a fireworks display of red, white, and blue?
2. What chemicals might be responsible for green, glittering firework stars?
3. Why are fireworks dangerous?

MATH SKILLS

Day 8

● **Half-Life**

If 100.0 g of carbon-14 decays until only 25.0 g of carbon is left after 11 460 y, what is the half-life of carbon-14?

1. List the given and unknown values.

Given: initial mass of sample = 100.0 g

final mass of sample = 25.0 g

total time of decay = 11 460 y

Unknown: number of half-lives = ? half-lives

half-life = ? y

2. Write down the equation relating half-life, the number of half-lives, and the decay time, and rearrange it to solve for half-life.

$$\text{total time of decay} = \text{number of half-lives} \times \frac{\text{number of years}}{\text{half - life}}$$

$$\frac{\text{number of years}}{\text{half - life}} = \frac{\text{total time of decay}}{\text{number of half - lives}}$$

3. Calculate how many half-lives have passed during the decay of the 100.0 g sample.

$$\text{fraction of sample remaining} = \frac{\text{final mass of sample}}{\text{initial mass of sample}} = \frac{25.0 \text{ g}}{100.0 \text{ g}} = \frac{1}{4}$$

$$\text{after one half-life} = \frac{1}{2}; \text{ after two half-lives} = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \text{ of sample}$$

Two half-lives have passed.

4. Solve for the half-life.

$$\frac{\text{number of years}}{\text{half - life}} = \frac{11\,460 \text{ y}}{2 \text{ half - lives}} = \frac{5730 \text{ y}}{\text{half - life}}$$

$$\text{half-life of carbon-14} = 5730 \text{ y}$$

Your Turn to Think

1. What is the half-life of a 100.0 g sample of nitrogen-16 that decays to 12.5 g of nitrogen-16 in 21.6 s?
2. All isotopes of technetium are radioactive, but they have widely varying half-lives. If an 800.0 g sample of technetium-99 decays to 100.0 g of technetium-99 in 639 000 y, what is its half-life?
3. A 208 g sample of sodium-24 decays to 13.0 g of sodium-24 within 60.0 h. What is the half-life of this radioactive isotope?

MATH SKILLS

Day 9

● **Half-Life** *continued***Sample Problem**

Thallium-208 has a half-life of 3.053 min. How long will it take for 120.0 g to decay to 7.50 g?

1. List the given and unknown values.

Given: half-life = 3.053 min

initial mass of sample = 120.0 g

final mass of sample = 7.50 g

Unknown: number of half-lives = ? half lives

total time of decay = ?

2. Write down the equation relating half-life, the number of half-lives, and the decay time, and rearrange it to solve for the total time of decay.

$$\text{total time of decay} = \text{number of half-lives} \times \frac{\text{number of min}}{\text{half - life}}$$

3. Calculate how many half-lives have passed during the decay of the 120.0 g sample.

$$\text{fraction of sample remaining} = \frac{7.50 \text{ g}}{120.0 \text{ g}} = 0.0625 = \frac{1}{16}$$

$$\text{after one half-life} = \frac{1}{2}; \text{ after two half-lives} = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4};$$

$$\text{after three half-lives} = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}; \text{ after four half-lives} =$$

$$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{16} \text{ of sample. Four half-lives have passed.}$$

4. Solve for the half-life.

$$\text{total time of decay} = 4 \text{ half-lives} \times \frac{3.053 \text{ min}}{\text{half - life}}$$

$$\text{total time of decay} = 12.21 \text{ min}$$

Your Turn to Think

4. If the half-life of iodine-131 is 8.10 days, how long will it take a 50.00 g sample to decay to 6.25 g?
5. The half-life of hafnium-156 is 0.025 s. How long will it take a 560 g sample to decay to one-fourth its original mass?

MATH SKILLS● **Half-Life** *continued*

6. Chromium-48 has a short half-life of 21.6 h. How long will it take 360.00 g of chromium-48 to decay to 11.25 g

Sample Problem

Gold-198 has a half-life of 2.7 days. How much of a 96 g sample of gold-198 will be left after 8.1 days?

1. List the given and unknown values.

Given: *half-life* = 2.7 days

total time of decay = 8.1 days

initial mass of sample = 96 g

Unknown: *number of half-lives* = ? half-lives

final mass of sample = ? g

2. Write down the equation relating half-life, the number of half-lives, and the decay time, and rearrange it to solve for the number of half-lives.

$$\text{total time of decay} = \text{number of half-lives} \times \frac{\text{number of days}}{\text{half - life}}$$

$$\text{number of half-lives} = \frac{\text{total time of decay}}{\frac{\text{number of days}}{\text{half - life}}}$$

3. Calculate how many half-lives have passed during the decay of the 96 g sample.

$$\text{number of half-lives} = \frac{8.1 \text{ days}}{\frac{2.7 \text{ days}}{\text{half - life}}} = 3.0 \text{ half-lives}$$

4. Calculate how much of the sample will remain after 3.0 half-lives.

final mass of sample = *initial mass of sample* × *fraction of sample remaining*

$$\text{fraction of sample remaining after three half-lives} = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$$

$$\text{final mass of sample} = 96 \text{ g} \times \frac{1}{8} = 12 \text{ g}$$

Your Turn to Think

7. Potassium-42 has a half-life of 12.4 hours. How much of an 848 g sample of potassium-42 will be left after 62.0 hours?

MATH SKILLS

● Half-Life *continued*

8. Carbon-14 has a half-life of 5730 y. How much of a 144 g sample of carbon-14 will remain after 1.719×10^4 y?
9. If the half-life of uranium-235 is 7.04×10^8 y and 12.5 g of uranium-235 remain after 2.82×10^9 y, how much of the radioactive isotope was in the original sample?

Chapter
25

HOLT PHYSICS
Mixed Review

Day 10

Subatomic Physics

1. Determine the number of neutrons in the following nuclei:

a. ${}_{92}^{235}\text{U}$ _____

b. ${}_{92}^{238}\text{U}$ _____

c. ${}_{93}^{239}\text{Pu}$ _____

d. ${}_{1}^2\text{H}$ _____

e. ${}_{1}^3\text{H}$ _____

f. ${}_{6}^{14}\text{C}$ _____

g. ${}_{7}^{17}\text{N}$ _____

h. ${}_{18}^{40}\text{Ar}$ _____

2. Consider the following pairs of nuclei: ${}_{6}^{12}\text{C}$, ${}_{6}^{13}\text{C}$ and ${}_{92}^{238}\text{U}$, ${}_{93}^{239}\text{Pu}$.

a. What does the first pair have in common?

b. What is the difference between the nuclei in the first pair?

c. What does the second pair have in common?

d. What is the difference between the nuclei in the second pair?

e. Describe the similarities between the two pairs.

f. Describe the differences between the two pairs.

IRW material copyrighted under notice appearing earlier in this book.

Chapter
25

HOLT PHYSICS
Mixed Review *continued*

- 3.** A nucleus decays by emitting a beta particle.
- a.** Compare the atomic mass of the new nucleus with that of the original nucleus.

- b.** Compare the atomic number of the new nucleus with that of the original nucleus.

- c.** Which nucleus would you expect to have a larger binding energy? Explain.

- d.** Which nucleus would have a larger mass defect? Explain.

- 4.** Fusion in the sun creates high temperatures that tend to make the sun expand. What keeps the reaction contained?

- 5.** A deuteron, ${}^2_1\text{H}$, may decay. Could it decay by emitting an alpha particle? Explain.

- 6.** What two quantities must be conserved in a nuclear reaction equation?

Holt Physics: Subatomic Physics
Essay

Assessment of Snow Day

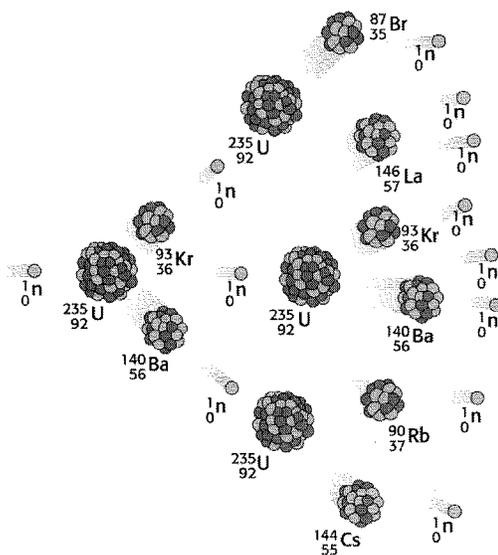
DIRECTIONS: The essay gives you an opportunity to show how effectively you can develop and express ideas. You should, therefore, take care to develop your ideas, present concepts logically and clearly, and use language precisely.

Your essay must be written on your own paper. You may use both sides of a single sheet of notebook paper. You will have enough space if you write on every line, avoid wide margins, and keep your handwriting to a reasonable size. Remember that people who are not familiar with your handwriting will read what you write. Try to write or print so that what you are writing is legible to those readers.

IMPORTANT REMINDERS:

- A pencil is required for the essay. An essay written in ink will receive a score of zero.
- Do not write your essay in your test book. You will receive credit only for what you write on a single sheet of notebook paper.
- An off-topic essay will receive a score of zero.

Think carefully about the concept presented in the following illustration and the assignment below.



ASSIGNMENT: Describe the nuclear chain reaction illustrated above. What are the starting substances in this process? What substances are produced? What important product allows this reaction to continue exponentially? Plan and write an essay in which you address these questions. Support your explanation with reasoning and examples taken from your reading, studies, experience, or observations.

Holt Physics: Subatomic Physics
Mathematics

DIRECTIONS: In this section, solve each problem using any available space on the page for scratch work. Then decide which of the choices given is best and fill in the corresponding circle on the answer sheet.

NOTES:

- The use of a calculator is permitted. All numbers used are real numbers.
- Figures that accompany problems in this test are intended to provide information useful in solving the problems. They are drawn as accurately as possible EXCEPT when it is stated in a specific problem that the figure is not drawn to scale. All figures lie in a plane unless otherwise indicated.

Reference Information	Rest Energy	Z	Isotope	Atomic Mass (u)
	$E_R = mc^2$	0	neutron	1.008 665
		1	hydrogen	1.007 825
	Binding Energy of a Nucleus	5	boron-10	10.012 936
	$E_{bind} = \Delta mc^2$	5	boron-11	11.009 305
		6	carbon-10	10.016 854
	Half-life	6	carbon-11	11.011 433
	$T_{1/2} = \frac{0.693}{\lambda}$	6	carbon-12	12.000 000
		6	carbon-13	13.003 355
		6	carbon-14	14. 003 242
	1 Ci = $3.7 \times 10^{10} \text{ s}^{-1}$	15	phosphorus-30	29.978 307
		15	phosphorus-31	30.973 762
		15	phosphorus-32	31.973 907
		88	radium-224	224.020 187
	88	radium-226	226.025 402	

- What is the total binding energy of ${}_{15}^{32}\text{P}$?
 - 31.97 MeV
 - 32.26 MeV
 - 270.85 MeV
 - 282.59 MeV
 - 290.77 MeV
- What is the difference in the binding energies of ${}_{5}^{10}\text{B}$ and ${}_{6}^{10}\text{C}$?
 - 3.650 MeV
 - 4.432 MeV
 - 60.320 MeV
 - 64.752 MeV
 - 125.072 MeV

GO ON TO THE NEXT PAGE

Mathematics *continued*

3. What is the binding energy per nucleon of $^{228}_{88}\text{Ra}$ in MeV?
- (A) 7.16 MeV/nucleon
 - (B) 7.64 MeV/nucleon
 - (C) 7.94 MeV/nucleon
 - (D) 12.45 MeV/nucleon
 - (E) 19.80 MeV/nucleon

4. What symbol is missing in the following radioactive-decay formula?
- $$^{22}_{11}\text{Na} \rightarrow ? + {}^0_1e + \nu$$
- (A) $^{22}_{12}\text{Ne}$
 - (B) $^{22}_9\text{Ne}$
 - (C) $^{21}_{10}\text{Ne}$
 - (D) $^{21}_{11}\text{Ne}$
 - (E) $^{22}_{10}\text{Ne}$

5. What symbol is missing in the following radioactive-decay formula?
- $$^{218}_{84}\text{Po} \rightarrow ? + {}^4_2\text{He}$$
- (A) $^{214}_{82}\text{Pb}$
 - (B) $^{22}_{82}\text{Pb}$
 - (C) $^{214}_{86}\text{Pb}$
 - (D) $^{216}_{82}\text{Pb}$
 - (E) $^{218}_{84}\text{Pb}$

6. Neptunium-239 decays by β^- emission to plutonium-239. What is the complete decay formula for this process?
- (A) $^{239}_{93}\text{Np} \rightarrow ^{235}_{91}\text{Pu} + {}^4_2\text{He}$
 - (B) $^{239}_{93}\text{Np} \rightarrow ^{238}_{93}\text{Pu} + {}^0_{-1}e + \bar{\nu}$
 - (C) $^{239}_{93}\text{Np} \rightarrow ^{239}_{94}\text{Pu} + {}^0_{-1}e + \bar{\nu}$
 - (D) $^{239}_{93}\text{Np} \rightarrow ^{239}_{92}\text{Pu} + {}^0_1e + \nu$
 - (E) $^{239}_{93}\text{Np} \rightarrow ^{240}_{93}\text{Pu} + {}^0_1e + \nu$

7. The half-life of ^{19}O is 26.9 s. What is the decay constant for the decay?
- (A) $2.58 \times 10^{-2} \text{ s}^{-1}$
 - (B) $3.72 \times 10^{-2} \text{ s}^{-1}$
 - (C) $2.69 \times 10^1 \text{ s}^{-1}$
 - (D) $3.88 \times 10^1 \text{ s}^{-1}$
 - (E) $3.88 \times 10^2 \text{ s}^{-1}$

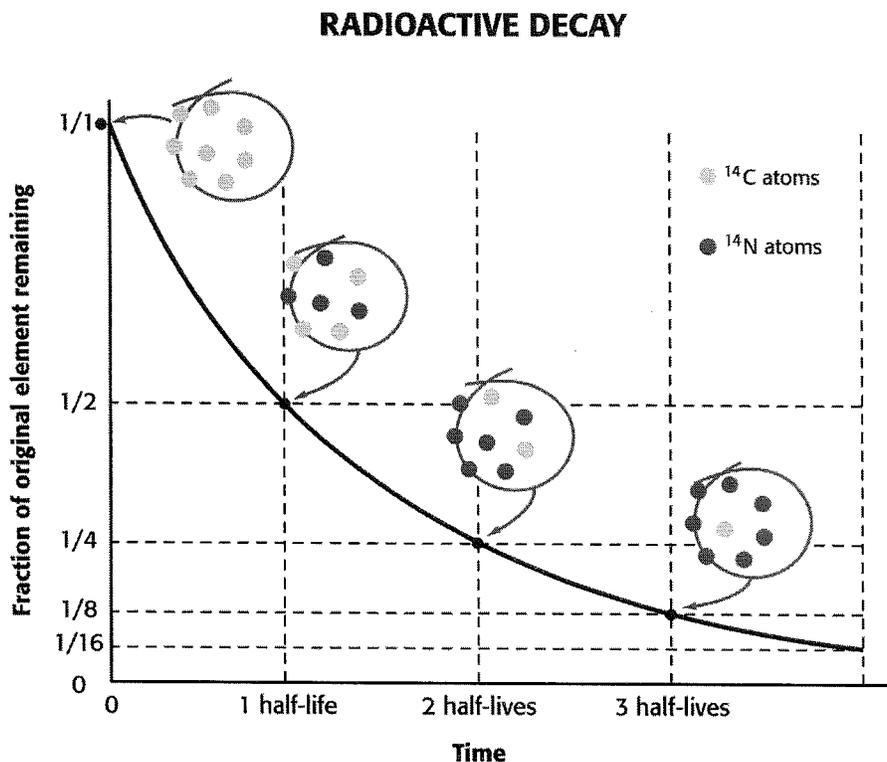
8. The half-life of $^{234}_{90}\text{Th}$ is 24.1 d. A thorium-234 sample contains 3.0×10^8 nuclei. How many thorium nuclei, in curies, will decay per second?
- (A) $2.7 \times 10^{-9} \text{ Ci}$
 - (B) $3.3 \times 10^{-7} \text{ Ci}$
 - (C) $2.3 \times 10^{-4} \text{ Ci}$
 - (D) $2.9 \times 10^{-2} \text{ Ci}$
 - (E) $9.9 \times 10^2 \text{ Ci}$

9. A scientist starts with $1.00 \times 10^{-2} \text{ g}$ of a pure radioactive substance and determines 10.0 min later that only $6.25 \times 10^{-4} \text{ g}$ of the substance remains. What is the half-life of this substance?
- (A) 0.625 min
 - (B) 2.50 min
 - (C) 4.00 min
 - (D) 6.25 min
 - (E) 16.0 min

GO ON TO THE NEXT PAGE

Mathematics *continued*

Questions 10 and 11 are based on the following graph of the decay of a sample of carbon-14.



- | | |
|--|---|
| <p>10. What percentage of the sample is carbon-14 after two half-lives?</p> <p>(A) 0.25%</p> <p>(B) 2%</p> <p>(C) 25%</p> <p>(D) 50%</p> <p>(E) 100%</p> <hr/> <p>11. The half-life of carbon-14 is 5715 y. Approximately how old is a sample if only $\frac{1}{8}$ of the original sample is carbon-14?</p> <p>(A) approximately 3 y</p> <p>(B) approximately 8 y</p> <p>(C) approximately 714 y</p> <p>(D) approximately 5715 y</p> <p>(E) approximately 17 145 y</p> | <p>12. Phosphorus-32 ($^{32}_{15}\text{P}$) has a half-life of 14.263 d. A sample contains 1.0×10^{10} phosphorus atoms initially. What is the approximate number of phosphorus atoms that will remain after 71 days?</p> <p>(A) about 1.4×10^8 atoms</p> <p>(B) about 3.1×10^8 atoms</p> <p>(C) about 7.0×10^8 atoms</p> <p>(D) about 2.0×10^9 atoms</p> <p>(E) about 5.0×10^{10} atoms</p> |
|--|---|

Holt Physics: Subatomic Physics
Sentence Completion

DIRECTIONS: For each question in this section, select the best answer from among the choices given and fill in the corresponding circle on the answer sheet.

13. The _____, Z , identifies the element and describes how many protons the nucleus has.
- (A) atomic number
 - (B) half-life
 - (C) isotope
 - (D) mass number
 - (E) neutron number
14. Nuclear decay that involves the emission of a helium-4 nucleus is called _____.
- (A) alpha decay
 - (B) beta decay
 - (C) electron emission
 - (D) gamma decay
 - (E) positron emission
15. In _____, two light nuclei combine to form a heavier nucleus.
- (A) alpha decay
 - (B) beta decay
 - (C) fission
 - (D) fusion
 - (E) gamma decay
16. The fundamental interaction in nature that is responsible for the binding of neutrons and protons into nuclei is called the _____ interaction.
- (A) electromagnetic
 - (B) friction
 - (C) gravitational
 - (D) strong
 - (E) weak

Holt Physics: Subatomic Physics
Reading Passages

The passages below are followed by questions based on their content; questions following a pair of related passages may also be based on the relationship between the paired passages. Answer the questions on the basis of what is stated or implied in the passages. For each question in this section, select the best answer from the choices given and fill in the corresponding circle on the answer sheet.

Questions 17 and 18 are based on the following passage, which is part of a letter written in August 1939 by physicist Albert Einstein to President Franklin Roosevelt.

Sir:

Line Some recent work by E. Fermi and
 L. Szilard, which has been communicated to
5 me in manuscript, leads me to expect that
 the element uranium may be turned into a
 new and important source of energy in the
 immediate future. Certain aspects of the
 situation which have arisen seem to call
 for watchfulness and if necessary, quick
10 action on the part of the Administration. I
 believe therefore that it is my duty to
 bring to your attention the following facts
 and recommendations.

 In the course of the last four months it
15 has been made probable through the work
 of Joliot in France—as well as Fermi and
 Szilard in America—that it may be
 possible to set up a nuclear chain reaction
 in a large mass of uranium, by which vast
20 amounts of power and large quantities of
 new radium-like elements would be
 generated. Now it appears almost certain
 that this could be achieved in the
 immediate future.

17. Given the date of this correspondence, why might Einstein recommend that the American president take “quick action,” as indicated in lines 9 and 10?
- (A) In 1939, overuse of nuclear energy in the United States was causing a worrisome shortage of uranium fuel.
 - (B) In 1939, the first detonation of a nuclear bomb had caused serious injuries and health risks to Americans.
 - (C) In 1939, the world was having an energy crisis that might be solved by the development of nuclear power.
 - (D) In 1939, political unrest in Europe gave countries incentive to develop powerful nuclear bombs.
 - (E) In 1939, overproduction of nuclear waste was causing dangerous overflow from dump sites.
18. What type of nuclear reaction is Einstein referring to when he uses the term “nuclear chain reaction” in line 18?
- (A) alpha decay
 - (B) beta decay
 - (C) fission
 - (D) fusion
 - (E) gamma decay

GO ON TO THE NEXT PAGE

Reading Passages *continued*

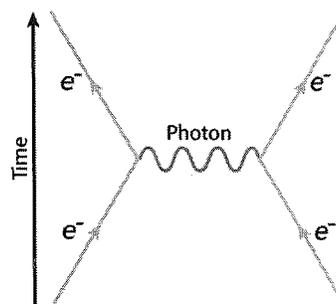
Questions 19 and 20 are based on the following passage and diagram.

“Poets say science takes away from the beauty of the stars—mere globs of gas atoms. Nothing is ‘mere.’ I too can see the stars on a desert night, and feel them. But do I see less or more?” said American physicist Richard P. Feynman in *The Feynman Lectures on Physics* (1966). Few would doubt that Feynman—a notorious prankster and an amateur artist, musician, and philosopher—understood more than a poet about the stars in the night sky, or at least how the particles that composed them behaved. Feynman jointly won the 1965 Nobel Prize in Physics for his work in the field of quantum electrodynamics, the mathematical study of the interactions between light and electrically charged particles.

Throughout his career, Richard Feynman had a reputation as an engaging lecturer, humorous writer, and brilliant physicist. From 1943 to 1945, Feynman worked on the Manhattan Project, Los Alamos National Laboratory’s secret research project to build the first atomic bomb. He later developed a way of representing electromagnetic interactions between particles through simple diagrams called Feynman diagrams, such as the one shown at right. His diverse career included participating in a government investigation of the 1986 Challenger space shuttle disaster, in which he famously demonstrated a flaw in one of the shuttle’s rubber gaskets.

Born on May 11, 1918 in the suburbs of New York, NY, Feynman was educated at MIT and Princeton and taught

at Cornell and Caltech. He married three times and had two children. Feynman died on February 15, 1988, at the age of 69, after years of battling abdominal cancer.



19. According to lines 15–19, quantum electrodynamics can involve interactions
- (A) between stars and planets
 - (B) between dark matter and light
 - (C) between photons and neutrons
 - (D) between photons and electrons
 - (E) between neutral particles and light
20. What type of fundamental interaction is illustrated in the Feynman diagram above?
- (A) electromagnetic
 - (B) friction
 - (C) gravitational
 - (D) strong
 - (E) weak

Holt Physics: Subatomic Physics
Improving Sentences

DIRECTIONS: For each question in this section, select the best answer from among the choices given and fill in the corresponding circle on the answer sheet.

Part of each sentence in items 21 and 22 is underlined. Below each sentence are five ways of phrasing the underlined material. Choice A repeats the original phrasing; the other four choices are different. Choose the answer you think produces the most accurate sentence.

Each sentence in items 23 and 24 contains either a single error or no error at all. If the sentence contains an error, choose the one underlined part that must be changed to make the sentence correct. If the sentence is correct, select choice E.

21. The binding energy of a nucleus is the difference in energy between its number of protons and number of neutrons.
- (A) number of protons and number of neutrons
 - (B) number of protons and number of electrons
 - (C) number of electrons and number of neutrons
 - (D) neutrons when bound and its neutrons when unbound
 - (E) nucleons when bound and its nucleons when unbound
22. During nuclear fission, an alpha particle is emitted and a new element is produced.
- (A) an alpha particle is emitted and a new element is produced
 - (B) an electron is emitted and a new element is produced
 - (C) a positron is emitted and a new element is produced
 - (D) a heavy nucleus splits into two lighter nuclei
 - (E) two light nuclei combine to form a heavier

23. Half-life is the time needed for all of the original nuclei of a sample of a radioactive substance to undergo radioactive decay.
- A
 - B
 - C
 - D
 - No error
 - E
24. Subatomic particles are either leptons, which include electrons and neutrinos, or hadrons, which are either protons or baryons. No error
- A
 - B
 - C
 - D
 - E