Lesson 11
Introduction to Modern Physics

Introduction: Connecting Your Learning

The previous lesson addressed light waves and the properties associated with light. In some cases, light behaves as a wave, and in other cases, light can be described as a particle. As demonstrated in this lesson, the basic building block of light takes on a model identity that lies somewhere between a particle and wave. Light is referred to as a quantum. A quantum can be thought of as a packet of energy with both particle and wave-like characteristics. This is essential to understanding the course to this point, and the information will be used in Lesson 12. The atom is the basis for all matter. Chemistry is the study of matter, and physics is the study of the behavior of matter.

Readings, Resources, and Assignments	
Required Textbook Readings	None

Check Prior Knowledge

Check your prior knowledge by matching these terms.

Term	Definition
Atomic number	The number of protons plus the number of neutrons in a nucleus
Atomic mass number	A quantum of light
Isotope	Negative charge
Atomic spectrum	Zero charge
Photon	The vertical columns on the periodic table
Periods	Positive charge
Atomic mass	High energy E&M radiation
Groups	The number of protons in the nucleus
Electron	The horizontal rows on the periodic table
Proton	The usual units are "amu"
Neutron	An element's fingerprint
Gamma ray	Atoms with the same atomic number, having a different number of neutrons

Focusing Your Learning

Lesson Objectives

By the end of this lesson, you should be able to:

1. Compare and contrast the basic components of an atom in terms of charge and relative mass.
2. Discuss the nature of the photoelectric effect and how the experimental evidence gained relates to the wave-particle duality concept of atomic theory.
3. Discuss the early conceptual models of the atom with the current models based on experimental evidence.
4. Discuss the Bohr model of the atom.
5. Explain how the presence of atomic spectra supports the current model of the atom.
6. Describe radioactive half-life.
7. Differentiate between various types of radiation.
8. Compare and contrast nuclear fusion and nuclear fission.

Approaching the Objectives

This lesson is comprised of five sections:

Section 1: Elements and Atoms

Section 2: Early Atomic Discoveries

Section 3: Atomic Models

Section 4: Radioactivity and Half-Life

Section 5: Fission and Fusion

Section 1: Elements and Atoms

View the video from Khan Academy on The Atom.

All matter is composed of tiny particles called *atoms*. Although atoms cannot be seen with the naked eye or even through an ordinary microscopic, many experiments have been performed to support the current model used to describe the atom. On the most basic level, an atom consists of a central structure that contains two distinct particles referred to as protons and neutrons. The mass of these particles is not exactly the same, but it is very close. For convenience, a unit called the atomic mass unit (amu) has been defined for these particles. Each has a mass of about 1 amu. The particles that make up the atom exhibit another property called electrical charge. Protons have a positive charge, and neutrons have a neutral charge. The atom has another type of particle that exists in space somewhere outside the nucleus of the atom. This particle is the electron. The charge on the electron is the same amount as the charge on the proton, but it is opposite in polarity. The charge is negative. The mass, however, is roughly 10,000 times less than the mass of a proton or neutron. The significance of these opposite charges is that opposite charges attract each other (like charges repel), and the electrons usually stay near the parent nucleus. If an electron is taken away or an extra electron joins the group, the particle is ionized. Ionized particles that are deficient or in excess of electrons are called *ions*. The electrons exist in various energy levels, and it is the arrangement of the electrons in the highest energy levels that determines how one atom becomes bonded (connected) to another atom to form a molecule.

Organize the information given above into a table for easy reference.

(You will find an example of the completed table at the end of the lesson.)

Particle	Mass (amu)	Charge (type)
Proton		
Neutron		
Electron		

The next section discusses atomic mass and the atomic mass numbers associated with different isotopes of the same element.

When the components described above are assembled by nature into discrete packages called atoms, most of the mass consisting of the protons and neutrons is "glued" together by the nuclear strong force. The electrons are found in various energy levels far outside the nucleus. If a scale model of the atom puts the nucleus (the size of a football) on the 50-yard line, the nearest electron would be outside the stadium. This illustrates that atoms are mostly comprised of empty space. Neutral atoms have an equal number of electrons and protons in order for the net charge to equal zero. Unequal numbers of electrons and protons result in charged particles (either positive or negative) referred to as ions. Positive ions are called cations and negative ions are called anions.

Atoms of a particular element contain the same number of protons. However, some of the atoms may contain a different number of neutrons. Atoms that contain the same number of protons but a different number of neutrons are referred to as isotopes. One common notation used to describe an atom is called "Z X to the A" notation.

$${}_{Z}\mathbf{X}^{A}$$

The Z number is the number of protons. The X stands for the chemical symbol of the element and the A number is the number of nucleons (i.e., neutrons plus protons).

For example, three isotopes of carbon are ${}_{6}C^{12}$, ${}_{6}C^{13}$, ${}_{6}C^{14}$. Complete the following with the correct responses. (You can check your answers at the end of the lesson.)

Each carbon atom has ______ protons.

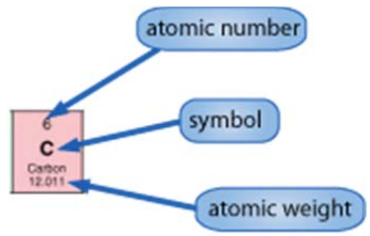
Each neutral carbon atom has ______ electrons.

The isotope ${}_{6}C^{12}$ has ______ protons and ______ neutrons.

The isotope ${}_6C^{13}$ has ______ protons and ______ neutrons.

The isotope ${}_6C^{14}$ has ______ protons and ______ neutrons.

The periodic table of the elements contains information about each element. For example:



The "6" is called the atomic number and refers to the number of protons in the nucleus. The "C" is the chemical symbol for carbon. The 12.011 is the weighted average of all naturally occurring isotopes of the element. The weighted average is calculated by considering the percent abundance of each of the isotopes. From the number 12.011, it is easy to see that most of the naturally occurring carbon found in nature is the isotope ${}_6C^{12}$. Carbon – 14 is a radioactive isotope of carbon that is discussed in a later lesson.

Math Challenge: Consider two isotopes of chlorine shown in the table below.

Isotope	Percent Abundance	Atomic Mass
Chlorine -35	75.78%	34.969
Chlorine- 37	24.22%	36.966

Note: The percent abundances add up to 100 percent.

Find the atomic mass of chlorine. (You can check your answer at the end of the lesson.)

The next section provides insight into the early atomic discoveries that have led to the present day model of the atom.

Section 2: Early Atomic Discoveries

View the video from Khan Academy on Orbitals.

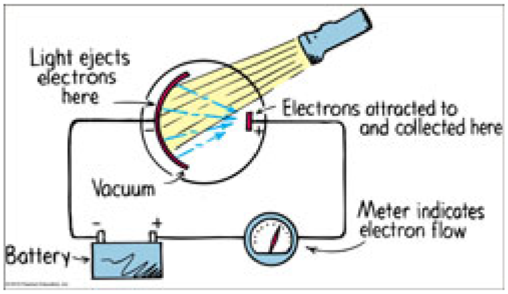
The early 1900s were an exciting time for physics. This era is often referred to as the birth of modern physics. There were heavy debates as to whether light was a particle or a wave.

Activity:

Conduct research on the Internet and/or search your textbooks to match the scientist with the discovery for which he or she is recognized.

Scientist	Discovery
J.J. Thomson	Atomic nucleus
Max Planck	Electron energy level and atomic spectra
Ernest Rutherford	Uncertainty Principle
Louis de Broglie	Wave nature of matter
Werner Heisenberg	Oil drop experiment
Neils Bohr	Discovered electron
Erwin Schrödinger	Photoelectric Effect
Robert Millikan	Wave equation

One classic experiment consisted of shining various colors of light onto a metal surface. The purpose of the experiment was to confirm that light is a wave and not a particle. Scientists observed that electrons were ejected from the metal at different energies depending on the color of the light used. This phenomenon has become known as the Photoelectric Effect.



As it turns out, the Photoelectric Effect experiment did not confirm that light was a wave, but instead supported the particle-like characteristics of light. Light has since been referred to as a quantum of energy. Another term to describe quantum is photon.

The previous lesson introduced the concept of atomic spectra. There is a direct relationship between atomic spectra and conclusions achieved from the Photoelectric Effect data.

When the electrons in an atom or ion are provided with additional energy from an outside source such as a burning flame, the elections become "excited" and move to a higher energy state. Only certain energy levels are allowed for each different kind of atom. One way to visualize this concept is to think in terms of the apartments on different floors of a high-rise apartment building. People do not live in between the different floors, and electrons don't live in between energy levels in the atom. When an electron moves to a higher energy state, it does not stay there very long. When the electron returns to its normal energy level, it has to relinquish the extra energy that is temporarily processed from the burning flame (or another source). The electron releases this energy in the form of electromagnetic radiation. If the frequency is the visible portion of the spectrum, it is seen as colored light. Some of the frequencies are lower than visible light (infrared) and some are higher (ultraviolet). Each frequency of the radiation emitted can be captured by an instrument and displayed as sort of a chemical "fingerprint" of the element. These chemical "fingerprints" are referred to atomic spectra. Analyzing the difference between the frequencies led to speculating what the variation in energy levels must be since the energy of the light is directly proportional to the frequency. The model for the light emitted is viewed as a discrete packet of energy that has both a wavelength and frequency and a specified quantity of energy. This packet is referred to as a photon of light. These protons are also called quanta. The branch of physics that studies this phenomenon in great mathematical detail is quantum mechanics.

Before going on to the next section, review the relationship between the energy of the photon and the color of light emitted.

Math Challenge: The energy of a photon of light is given by $E = h \cdot f$ where E is the energy of the photon and f is the frequency. The constant "h" is known as Planck's constant and is the constant of proportionality between energy and frequency for a photon of light. The value of h is 6.63×10^{-34} Joules. Notice that when his multiplied by f, the units of seconds cancel and the energy of the photon is given in Joules, which is the SI unit for energy.

Problem: When an electron falls from the fourth to the second energy level, it emits a photon of green light with a frequency of 5.80×10^{14} Hz. Calculate the energy of this photon. **Hint:** 1 Hz is the same as the reciprocal of seconds.

Check your answer at the bottom of the lesson.

A more convenient unit to use when working with energy on the atomic scale is the electron-volt (eV). The conversion factor is $1 \text{ eV} = 1.6 \times 10^{-19}$ J.

In the problem above, what is the energy of the green light expressed in eV?

Check your answer at the bottom of the lesson.

Note: This number is much more convenient to work with.

The next section shows how each electron within the atom possesses a unique set of parameters that distinguish that electron from any other electron in the atom.

Section 3: Atomic Models

Electrons in an atom are described by assigning each electron to a set of quantum numbers such that every electron can be uniquely identified. An analogy might be that every person has at least one characteristic that makes that individual different from all others. The parameter might be: (1) name, (2) address, (3) telephone number, and (4) gender. In the quantum world, the four characteristics that distinguish one electron from another are (1) energy level, (2) shape of the most probable location of the electron, (3) the orientation of the particular shape in terms of the x-y-z axes and (4) the direction of the spin of the electron (CW or CCW). **Note:** There is more to this last term, but this is a convenient way to model the concept.

The first quantum number, n, refers to the principal energy level of the electron. The principal quantum is always an integer (i.e., 1, 2, 3 .... etc.). (In later lessons, this principal quantum number is correlated to the rows on the Periodic Table of the Elements.)

The next quantum number is sometimes referred to as the angular momentum quantum number and describes the shape of the probably cloud where the electron is most likely to exist. The symbol for this quantum number is "ℓ", and "ℓ" can have values that range from 0 all the way to (n-1). Each value of "ℓ" corresponds to a particular shape.

The third quantum number is called the magnetic quantum number and provides a visual representation of how the shape is aligned with respect to the x-y-z coordinate axes. The symbol for the third quantum number is ml. The allowable values for m_ℓ range from (ℓ -1).......0.......

(ℓ +1). For example, if n=1, then l can only be (n-1) or zero and m_ℓ can only be zero.

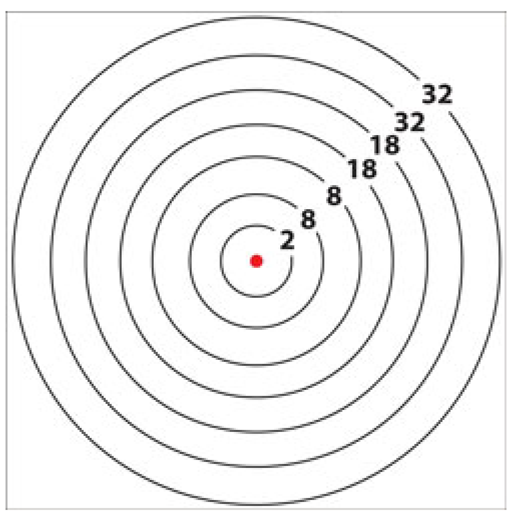
In more user-friendly terms, this means that for the lowest energy level that an electron can exist (n=1), there is only one shape (ℓ = 0 means spherical) and a sphere has only one orientation (m_ℓ = 0 means one orientation).

More detail and examples are provided in the next section.

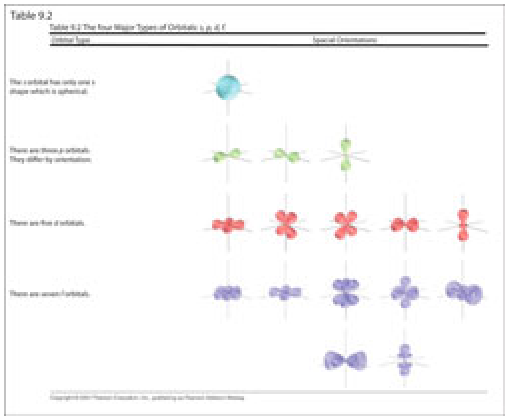
This treatment of electron location may seem very abstract; however, this provides the foundation and framework for explaining how atoms bond together to form molecules that will be discussed in lessons that follow.

The model of the atom has steadily progressed throughout the last century. Early models visualized the electrons orbiting the nucleus in perfect circles of certain allowed radii. The rules that govern classical physics were applied to electrons orbiting the nucleus. Only certain values of electron energy were allowed along with restricted values of the electron's angular momentum.

One of the goals of the model was to explain the atomic spectra discussed in the previous sections. The model constructed by Niels Bohr, which used the rules from classical physics, was able to correlate the difference in energy levels for a single electron hydrogen atom with the atomic spectra produced by hydrogen. This model was much less accurate in predicting spectra for multi-electron atoms, but nevertheless it retains a place in modern science as a primary stepping-stone to more recent models. The next model that followed was an extension of the Bohr model of the single electron hydrogen atom. This is sometimes referred to as the Shell Model. Each circle in the model represents an energy level that can contain a specified number of electrons. Once the level was full, any additional electrons had to move to a higher level. The numbers shown (i.e., 2, 8, 8, 18, etc.) represent the maximum number of allowed electrons in a particular energy level.



More recent models do not predict the exact location of an electron around the nucleus, but instead, define a 90% probably region where the electrons may be found at any given time. The orbitals (not to be confused with Bohr's orbits) shown in the diagram represent graphical solutions to a three-dimensional equation that considers an electron as waves around the nucleus. The actual equation is far beyond the level of this class; however, it is instructive to realize that the illustrations shown are merely graphical solutions to a three-dimensional equation that models the atom.



The table shown relates to the quantum numbers discussed in previous section. The s orbitals are each spherical. This corresponds to an ℓ of 0. Each s orbital may contain two electrons. The p orbitals are dumbbell shaped and have $\ell = 1$. Since each orbital can contain two electrons and there are three p orbitals (i.e., p_x, p_y, p_z), the *p* orbitals in each principal energy level can contain a total of 2 x 3 = 6 electrons. Note the shape of each p orbital is the same, but the orientations are different. This corresponds to the three different values of the third quantum number, m_ℓ.

In the d and f orbitals, there are different shapes as well as different orientations.

Section 4: Radioactivity and Half-Life

View these videos from Khan Academy on Types of Decay and Half-Life.

There are five possible types of nuclear transformations. The reason these transformations occur is to achieve the most stable configuration in the nucleus. Nature strives to obtain the lowest possible energy configurations whenever it can. When an object is dropped, it falls to a lower potential energy. Particles within an atomic nucleus also strive to reach the lowest possible energy state.

The two primary particles in the nucleus are the protons and the neutrons. For the lighter nuclei, the most stable neutron to proton ratio is roughly one to one. Isotopes of the same element have different numbers of neutrons. When the neutron to proton ratio shifts too far in any direction (i.e., too high or too low), nature responds by either converting a proton into a neutron or vice versa. In either case, a particle is released from the nucleus so that charge and mass are conserved. These particles are referred to as Beta particles. Beta particles can either be positive or negative. The mass of a Beta particle is the same as the mass of an electron.

Example:

Too many neutrons compared to protons: Nature responds by converting a neutron into a proton.

${}_{0}n^{1} \rightarrow {}_{1}p^{1} + {}_{-1}\beta^{0} + \gamma$ (gamma radiation) In this case, a Beta minus particle is released.

Too many protons compared to neutrons: Nature responds by converting a proton into a neutron.

${}_{1}p^{1} \rightarrow {}_{0}n^{1} + {+}\beta^{0} + \gamma$ (gamma radiation)

Sometimes the nuclei have been "excited" by another source. This means that the nucleus has extra energy. It releases this energy by emitting the energy in the form of high-energy electromagnetic radiation (gamma rays). **Note:** Gamma radiation can be released in any nuclear transformation.

Heavier atoms such as Uranium or Plutonium become unstable due to a mass-to-volume instability. Nature reacts to this instability by releasing a much more massive particle than the Beta (mass of an electron). The particle released is an alpha particle, which is identical to a helium nucleus ${}_2He^4$. The mass of an alpha particle is roughly 4 amu compared to 0.00055 amu for the Beta particle.

The fifth type of nuclear reaction is referred to as electron "K capture." The "K" is a holdover from the earlier shell model where the electron shells were named K, L, M, etc. with K being the shell closest to the nucleus. This reaction can be viewed as:

${}_{-1}e^0 + {}_1p^1 \rightarrow {}_0n^1 + \gamma$ (gamma radiation).

Note that the net result is to convert a proton into a neutron just like the Beta plus decay. To predict which reaction would occur (Beta plus decay or "K" capture) in order to relieve the nuclear instability is beyond the scope of an introductory science course.

Radioactivity is a double-edged sword. Many useful aspects of radioactivity enhance human existence and produce a benefit to the environment. On the other hand, several aspects of radioactivity can be very harmful to the environment.

Nuclear radiation is all around us every day. Some of it can be harmful if it used carelessly, or some radiation can be beneficial if used in the right manner. Exposure to radiation can be measured in units of rads. One rad is equivalent to 0.01 Joules of energy absorbed per kilogram of tissue. Since not all radiation has the same effect on living tissue, another unit referred to as the rem is used to account for the varying damage that can be incurred by different types of radiation.

Radioactive Decay

Radioactive decay is one of the more practical aspects of nuclear radiation. Knowing the rate at which isotopes undergo radioactive decay allows scientists to make accurate estimations of the age of certain materials.

The rate of radioactive decay differs between isotopes over a very wide range. Some isotopes decay and become another isotope or element in fractions of a second, while other isotopes take millions of years to decompose. In nature, when the rate that a particular quantity changes is directly proportional to the quantity that exists at a particular time, the rate of increase (or decrease) is referred to as exponential increase (or decrease). For example, the rate of population increase is proportional to the number of people present. This is an exponential function.

The term half-life is used to represent the time is takes for a sample of radioactive material to decay to one-half its original value. Half-lives for radioactive isotopes vary from less than a microsecond to more than thousands of years. One common use of this concept is using half-life to determine the age of ancient remains that were once living.

Carbon is an element found in most living organisms. Most carbon is composed of the isotope ${}_6C^{12}$. There is, however, a small percentage of the radioactive carbon isotope ${}_6C^{14}$ in every sample of living material that contains carbon. As shown in a previous section, the carbon-14 isotope decays to nitrogen over a long period. The half-life for this process is 5,730 years.

This means when an organism dies, no more carbon-14 is ingested, and the ratio of carbon-12 to carbon-14 starts to change. Every 5,730 years the remaining amount of carbon-14 is half of what it used to be.

Practically, this means that the decay rate measured by a counting instrument is directly proportional to the number of carbon-14 nuclei present. Decay rates can be compared between ancient samples and modern samples, and the ratios can be used to calculate the age of the ancient samples.

This same method can be used to estimate the age of rocks by comparing the ratio of lead (Pb) -206 to uranium (U) -238, since the half-life for the transformation of U-238 to Pb-206 is known. This technique has lead to the estimation that the Earth's crust is about 4.3 billion years old.

Example: U-238 decays very slowly with a half of 4.47 billion years. What percentage of a sample of U-238 would remain after 13.4 billion years?

Solution: Since the half-life is 4.47 billion years, 13.4 billion/4.47 billion equals about 3 half-lives.

So, after three half-lives, 12.5 % of the original sample remains.

Math Challenge:

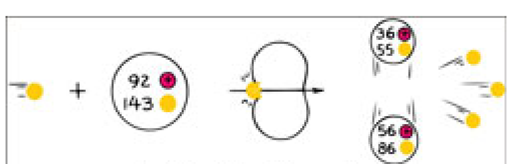
The half-life of iodine-131 is 8.1 days. How long will it take for 75% of a sample of iodine-131 to decay?

Check your answer at the bottom of the lesson.

The next section examines nuclear fission and nuclear fusion. Fission occurs when the nucleus of an atom is split apart, and the mass difference between the original nucleus and the products is converted into energy. Nuclear fusion occurs when two light nuclei come together to form a heavier nucleus and release a large amount of energy.

Section 5: Fission and Fusion

Nuclear fission is the basic process that is responsible for producing energy in nuclear power plants. The basic reaction involves a neutron colliding with a heavy atom such as Uranium-235. When the collision occurs, the U-235 atom splits into two or more (usually two) smaller atoms that may also be unstable and undergo further nuclear reactions. The two atoms that are "born" from the collision are referred as first exited daughters. Along with these atoms, several neutrons may be released. These neutrons go on to cause further fissions. This is the basis of the chain reaction that keeps causing more fission reactions. Each fission reaction is accompanied by a conversion from mass to energy, and the energy is released. The energy goes on to heat primary water that is under high pressure. This heat is then transferred to secondary water that is isolated from the radioactive primary water. The heated water produces steam, which drives turbines to produce electricity in much the same way that coal powered plants produce steam to drive turbines. The fission reaction looks like this. The actual atoms that are produced and the number of neutrons released can vary, but the conservation of charge and the conservation of mass must be consistent.



$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{91}_{36}Kr + ^{142}_{56}Ba + 3(^{1}_{0}n)$$

In the above reaction, the conservation of charge is satisfied by the bottom numbers. They must be the same on both sides of the arrow. Since 92 minus 36 equals 56, the missing atom must be Barium (Ba) since that element has an atomic number of 56.

The mass number is found by comparing the mass on the left side of the arrow (1 + 235) with the mass on the right side of the arrow (91 + X + (3x1)). So 236 = 91 + X + (3x1).

This means that the mass number of Ba is 142.

So the reaction may be written:

$_0n^1 + {}_{92}U^{235} \rightarrow {}_{52}Te^{137} + {}_{42}Ba^{142} + 3\ {}_0n^1$ + Energy

Math Challenge: Estimate how many fissions must occur each second to supply a day's energy to a private household in temperate climate (about 55 kilowatt-hrs). Assume each fission releases 200 MeV (million electron volts).

1 eV = 1.6×10^{-19}J.

1 watt = 1 J/s

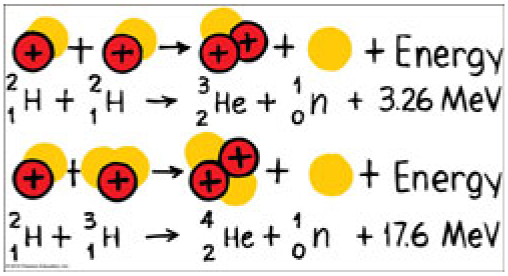
Check your answer at the end of the lesson.

Activity: find the missing items in the nuclear reactions below. The answers can be found at the end of the lesson.

$_0n^1$	+ $_{92}U^{235}$ →	$_{36}Kr^{92}$ +		+ 3 $_0$n1
$_0n^1$	+ $_{92}U^{238}$ →		$_{40}Zr^{97}$	+ 4 $_0n^1$
$_0n^1$		$_{36}Kr^{91}$ +	$_{56}Ba^{142}$	+ 3 $_0n^1$
$_0n^1$	+ $_{94}Pu^{239}$ →	$_{52}Te^{137}$ +	$_{42}Mo^{99}$ +	

Nuclear fusion is the opposite of nuclear fission. Fusion occurs when two lighter nuclei come together to form a heavier nucleus. This process also releases huge amounts of energy.

A prime example of nuclear fusion occurs in the Sun.



On the Sun, four hydrogen nuclei fuse in several steps to form one helium nucleus. The mass of the four hydrogen nuclei is greater than the mass of the helium nucleus that is produced. This mass difference is converted to energy. The fusion of one helium nucleus is about 25 MeV. Compare this to the energy released by one molecule of dynamite. This is about 20 eV, which is about a million times smaller.

Another way to visualize the fusion reactions on the Sun is to consider the following proton-proton chain.

1. First, two hydrogen nuclei fuse together to produce "heavy hydrogen" and release a beta particle:

   $_1H^1 + {_1H^1} \rightarrow {_1H^2} + {_{+1}\beta^0}$

2. This is followed by the product of this reaction combining with another $_1H^1$.

   $_1H^1 + {_1H^2} \rightarrow {_2He^3} + \gamma$ (gamma ray)

The reaction above happens over and over producing $_2He^3$. The $_2He^3$ react to form helium and the release of protons.

$_2He^3 + {_2He^3} \rightarrow {_2He^4} + 2\ {_1H^1}$.

Even though fusion is capable of releasing huge quantities of energy, the energy is hard to control due to the extreme temperatures involved. This is one of the challenges facing engineers today.

Summarizing Your Learning

This lesson included a brief introduction to atomic nomenclature. The basic sub-atomic particles were described in terms of mass and charge and how they fit into the structure of the atoms. Atomic spectra were shown to provide the link between experimental evidence and the present model of the atom in terms of electronic structure. The lesson also focused more clearly on the nucleus of the atom and investigated the transformations that take place in the nucleus. Understanding nuclear transformations leads to a better understanding of the benefits of radioactivity and using nuclear power to meet energy demands. Radioactivity is all around and is a part of everyday life. Concerned citizens are called upon to make intelligent decisions concerning how radioactivity is used in the environment. It is important to recognize the pros and cons of using radioactivity to produce the energy needs of society and maintain a sustainable environment. The next lesson investigates the concept of general and special relativity, which is one of the most exciting fields in physics.

Practice Answers

Check Prior Knowledge

Term	**Definition**
Atomic number	The number of protons plus the number of neutrons in a nucleus
Atomic mass number	A quantum of light
Isotope	Negative charge
Atomic spectrum	Zero charge
Photon	The vertical columns on the periodic table
Periods	Positive charge
Atomic mass	High energy E&M radiation
Groups	The number of protons in the nucleus
Electron	The horizontal rows on the periodic table
Proton	The usual units are "amu"
Neutron	An element's fingerprint
Gamma ray	Atoms with the same atomic number, having a different number of neutrons

Section 1: Elements and Atoms

Organize the information given above into a table for easy reference.

Particle	Mass (amu)	Charge (type)
Proton	1	Positive
Neutron	1	Neutral
Electron	1/10,000	Negative

Each carbon atom has ________6________ protons.

Each neutral carbon atom has _______ 6_________ electrons.

The isotope $_6C^{12}$ has ______6________ protons and ______6______ neutrons.

The isotope $_6C^{13}$ has _______6_______ protons and ______7______ neutrons.

The isotope $_6C^{14}$ has ______6________ protons and ______8______ neutrons.

Find the atomic mass of chlorine. 35.453

Section 2: Early Atomic Discoveries

Match the scientist with the discovery.

Scientist	Discovery
J.J. Thomson	Discovered electron
Max Planck	Photoelectric Effect
Ernest Rutherford	Atomic nucleus
Louis de Broglie	Wave nature of matter
Werner Heisenberg	Uncertainty Principle
Neils Bohr	Electron energy level and atomic spectra
Erwin Schrödinger	Wave equation
Robert Millikan	Oil drop experiment

Calculate the energy of this photon. **Hint:** 1 Hz is the same as the reciprocal of seconds. 3.85×10^{-19} J

In the problem above, what is the energy of the green light expressed in eV? 2.40 eV.

Section 4: Radioactivity and Half-Life

The half-life of iodine-131 is 8.1 days. How long will it take for 75% of a sample of iodine-131 to decay?

IF 75% DECAYS, THAT MEANS 25% REMAINS. THIS OCCURS AFTER 2 HALF-LIVES. SO, 2 X 8.1 DAYS = 16.2 DAYS

Section 5: Fission and Fusion

Math Challenge: Estimate how many fissions must occur each second to supply a day's energy to a private household in temperate climate (about 55 kilowatt-hrs). Assume each fission releases 200 MeV (million electron volts).

1 eV = 1.6×10^{-19}J.
1 watt = 1 J/s

1.15×10^{13} FISSIONS PER SECOND. THIS IS ON THE ORDER OF 10,000 BILLION FISSIONS PER SECOND!!

Find the missing items in the nuclear reactions below

${}_0n^1$	+ ${}_{92}U^{235}$ →	${}_{36}Kr^{92}$ +	${}_{56}Ba^{141}$	+ 3 0n1
${}_0n^1$	+ ${}_{92}U^{238}$ →	${}_{52}Te^{138}$	${}_{40}Zr^{97}$	+ 4 ${}_0n^1$
${}_0n^1$	${}_{592}U^{235}$ →	${}_{36}Kr^{91}$ +	${}_{56}Ba^{142}$	+ 3 ${}_0n^1$
${}_0n^1$	+ ${}_{94}Pu^{239}$ →	${}_{52}Te^{137}$ +	${}_{42}Mo^{99}$ +	4 ${}_0n^1$