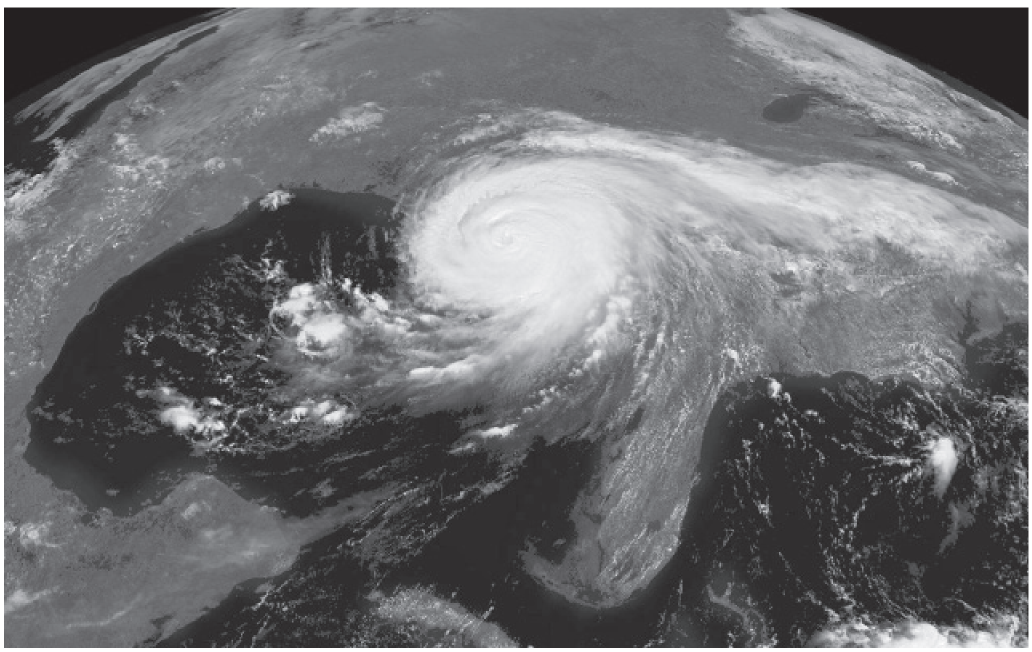
SAMPLE PAGES FOR

PASSING THE GEORGIA HIGH SCHOOL SCIENCE TEST

2006 EDITION



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CONTEMPORARY PUBLISHING COMPANY OF RALEIGH, INC.
6001-101 Chapel Hill Road, Raleigh, NC 27607 • (919) 851-8221
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Chapter 8

RADIOACTIVITY

SPS3. Students will distinguish the characteristics and components of radioactivity.

- **a. Differentiate among alpha, beta and gamma radiation.**
- **b. Differentiate between fission and fusion.**
- **c. Explain the process of half-life as related to radioactive decay.**
- **d. Describe nuclear energy, its practical application as an alternative energy source, and its potential problems.**

Section 8.1 Nuclear Reactions

What is Nuclear Radioactivity?

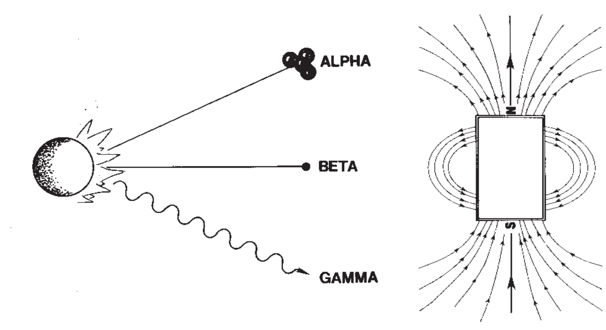
In a chemical reaction, electrons are gained, lost or shared. The nucleus does not change and no new elements are formed. In a **nuclear reaction**, the nucleus of the atom changes and new elements are formed. **Nuclear radioactivity** or radioactive decay is the spontaneous breakdown of the nucleus of some kinds of atoms. Particles and energy are given off and are called **nuclear radiation**. It is important to realize that in a nuclear reaction a lot more energy is released than energy given off in a chemical reaction. The new elements are more stable than the original elements. Elements with unstable nuclei are called **radioisotopes.** Radioisotopes are usually unstable because they have more neutrons than protons in their nucleus. Carbon-14 has an unstable nucleus. Carbon-14 has 6 protons and 8 neutrons. There are some radioactive elements with atomic numbers 1 to 83. All elements greater than atomic number 83 are radioactive.

Don't forget!

The number *14* in Carbon-14 is the mass number which tells us the number of protons and neutrons.

Types of Radiation

Subatomic particles are given off during a nuclear reaction. Particles are emitted so that the atom becomes more stable. **Transmutation** is the process of a nucleus changing so that a new element is formed. There are three types of transmutations described below.



Alpha particles are the largest radioactive particles, and therefore do not penetrate material as much as beta particles, which are fast-moving and small. Gamma radiation is the most dangerous due to the fact that it can penetrate living tissue

Alpha (α) Radiation. Alpha (α) particles are Helium ($^{4}_{2}He$) nuclei. This means they have two protons and two neutrons in their nucleus. Alpha particles are given off in alpha radiation. These particles are larger than the beta and gamma radiation. An example of an alpha particle given off is shown in the following equation:

$$^{238}_{92}U \Rightarrow {}^{4}_{2}He + {}^{234}_{90}Th$$

Notice the alpha particle is the product. Also, notice that the sum of the mass numbers on the product side equals the sum of the mass numbers on the reactant side. In the above equation we started with a mass number of 238 in Uranium. The products mass numbers add up to 238. Also, Uranium has an atomic number of 92. The sum of the atomic numbers of He (2) and Th (90) is 92. Alpha radiation would do the most damage to our body if it could get inside our body due to its high ionizing power. Ionization is the ability of the radioactivity to change atoms to ions.) It is stopped by our skin though and cannot get inside our body.

Beta (β) Radiation. Beta (β) radiation occurs when an element has too many neutrons. More than a 1:1 ratio of neutrons to protons causes instability. One of the neutrons is changed to a proton and an electron to make the nucleus more stable. The electron is given off or **emitted.** The electron given off is called a beta particle. A beta particle may be represented as $^{0}_{-1}$ or $^{0}_{-1}e$. An example of a beta particle given off is shown in the following equation:

$$^{14}_{6}C \Rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$$

Notice the beta particle has a -1 charge like an electron. The atomic number of Carbon is 6 and the new product has an atomic number of 7 (7 + -1 = 6).

Gamma (γ) Radiation. Gamma (γ) radiation is high energy electromagnetic waves given off from the nucleus that usually occurs with an alpha or beta particle being given off. Gamma radiation does not have mass or charge so it does not alter the mass or charge of the nuclear equation. An example of alpha and gamma radiation given off is shown in the following equation:

$$^{238}_{92}U \Rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + {}^{0}_{0}\gamma$$

Gamma radiation is the most dangerous radiation due to the fact that it can penetrated living tissue. It can be stopped with thick steel or thick concrete.

THE PROPERTIES OF THE THREE TYPES OF RADIOACTIVE EMISSION AND SYMBOLS

Radiation	Description	Nuclear Symbol	Penetration	Ionization
Alpha	A Helium nucleus of 2 protons and 2 neutrons; Mass = 4	$^{4}_{2}He$	Low penetration, but biggest mass; stopped by a few cm of air or thin sheet of paper	Very high ionizing power; the biggest mass of the three so it packs the biggest punch
Beta	High kinetic energy electrons; Charge = -1, Mass = 1/1850	$^{0}_{-1}e$ or $^{0}_{-1}$	Moderate penetration; stopped by a few mm of metals like aluminum	Moderate ionizing power with a smaller mass and charge
Gamma	Very high frequency electromagnetic radiation; Mass = 0, Charge = 0	$^{0}_{0}\gamma$	Very high penetration, but smallest mass and charge; most radiation stopped by a thin layer of steel or concrete, but not lead	The lowest ionizing power of the three; it has no mass or charge so not much of a punch when colliding with an atom

Section 8.1 Practice

1. Which nuclear particle emitted is heavy and slow moving?

2. Which nuclear particle is blocked by paper or skin?

3. Which nuclear particle is blocked by aluminum foil?

Finish the following equations. What type of radioactive decay occurs in each?

4. $^{239}_{94}Pu \Rightarrow {}^{4}_{2}He + ?$

5. $^{42}_{19}K \Rightarrow {}^{0}_{-1}e + ?$

6. $^{226}_{88}Ra \Rightarrow {}^{222}_{86}Rn + ?$

7. $^{239}_{92}U \Rightarrow {}^{239}_{93}Np + ?$

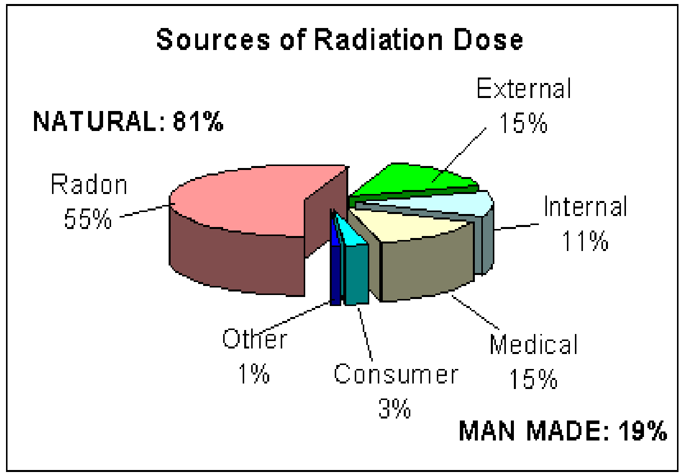
8. $^{122}_{5}B \Rightarrow {}^{0}_{-1}e + ?$

Section 8.2 Radiation Exposure

Check it out!

Potassium-40 is a radioactive isotope naturally occuring the soil and also found in foods.

We are exposed to radiation in our daily life. We are exposed to radiation naturally. We are exposed to radiation by cosmic rays that hit the earth from outer space. We can get more exposure to cosmic rays when we fly. Also, radioisotopes are released from rocks, soil and ground water as natural radioisotopes decay. Radon-222 is a radioactive isotope found in the atmosphere and we are exposed to it. Other possible exposure comes from foods we eat.



The unit for measuring radiation is called **rem**. It stands for Roentgen equivalent, man. Roentgen discovered radiation and the units were named after him. Rem measures the amount of radiation that causes ionization in human tissue. **Ionization** is radiation in large enough amounts to produce ions in substances through which it passes. If this occurs, it could damage our organs.

When we are naturally exposed to radiation it is called **background radiation**. Eighty one percent of our exposure comes from background radiation. This exposure is about 300 mrems (0.3 rems per year) per year. We also get some exposure if we have X-rays or nuclear medicine tests in the hospital. We may be exposed by living close to a nuclear power plant or coal mining area. We may get a small amount from nuclear fallout (prior nuclear weapons testing in the U.S.). With tests and our other exposure the average exposure to radiation is 0.36 mrems. This amount is considered safe by the National Environmental Protection Agency (EPA).

Benefits of Radioactivity

Radiation can be useful to us. In medicine, we use radioactive substances called **tracers** to help us detect tumors. We can drink or have radioisotopes injected and then watch the flow of the radioisotope in our body cells. Tracers are also used to monitor water flowing underground. Nuclear radiation is not just used in medical tests but also to treat cancer.

This symbol stands for food that has been irradiated.

We use radiation to help reduce spoilage in our food. When we radiated our food we call it **irradiation.** Irradiated food has been exposed to gamma rays and helps our food to last much longer. The food is exposed to gamma radiation which kills bacteria and mold which spoils our food. It does not make our food radioactive. Radioisotopes also sterilize medical equipment used in surgery.

We use radioactive material in smoke detectors to prevent fires. Also, Carbon-14, a radioactive material is used to date artifacts from the past. Nuclear power plants are built to provide much needed electricity. As you can see there are many benefits to radioactivity.

Could Radiation Harm Us?

The International Symbol for Nuclear radiation

The amount of radiation, the amount of time you are exposed to it and the type of radiation would be factors in deciding if radiation would harm us. Remember, alpha radiation does not penetrate skin so it would be harmful if only it found a way inside our body. Beta and gamma radiation penetrate the skin but also pass right through the body so this would limit the amount of time you were exposed.

If the amount of radiation is sufficient, the particles enter the body, collide with cells and cause damage. Low doses may not kill the cells but large doses of radiation will kill the cells. Radiation can cause cancer by mutating the normal cells and then causing them to divide uncontrollably. **Radiation sickness** occurs when high doses of radiation occur. How harmful the radiation sickness depends on the type, time and dose of radiation.

Radiation can break the bonds in molecules and tear them apart. Low levels of radiation will only harm a few molecules and the body will be able to repair the damage without killing our body cells. Beta and gamma radioactive decay are more dangerous (outside the body) than alpha decay because they penetrate the skin and can harm our internal organs. If alpha radiation could get inside our body it would be the most dangerous because it would do damage in a specific area whereas beta and gamma would probably pass through the body.

The penetrating power of these types of radiation indicates the damage they may do to living tissue, causing radiation burns, genetic mutations (a harmful change in our cells that can be passed on to generations), cancer and death.

How can we get less exposure to radiation? We cannot control cosmic rays but we can control how often we fly. We can measure radon-222 exposure in our homes with a test kit sold in most drug stores. We can decide about the number and necessity of medical tests that expose us to these high energy particles.

Section 8.2 Practice

1. What is background radiation?

____

____

2. What are some of the benefits of radioisotopes?

____

____

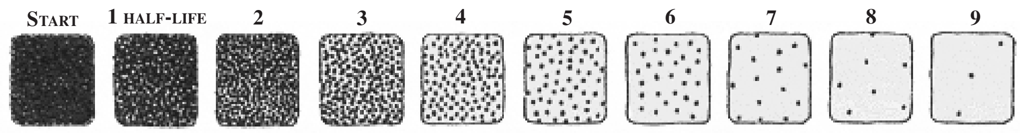
3. When are radioisotopes harmful?

____

____

Section 8.3   Half-Lives

When we look at the type of radiation and how harmful it is we need to know the radioisotopes half-life. Half-life is the amount of time that it takes for half of the nuclei in a sample to undergo radioactive decay.



Decay Rate of Radioactivity. After ten half lives, the level of radiation is reduced to one-thousandsth.

Each radioactive element has its own characteristic half life. The half-life of Carbon is 5700 years. Since Carbon-14 is found in all living or once-living organisms, its half-life can be used to determine the time of death of these materials.

The following table shows a 10.0 gram sample of Carbon-14. After one half-life (5.700 years) the amount left would be 5.0 grams. When another 5700 years passes (another half-life) only 2.5 grams of Carbon-14 is left. As each half-life occurs, one half the Carbon-14 is no longer present. It decays and becomes Nitrogen-14.

AMOUNT OF CARBON-14	HALF-LIFE	YEARS
10.0 g	start	0
5.0 g	1	5,700
2.5 g	2	11,400
1.25 g	3	17,100
0.625 g	4	22,800

$$^{14}_{6}C \Rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$$

Each time a half-life occurs, radioactive decay has taken place. The Carbon-14 that is gone has changed to Nitrogen and emitted beta particles and energy. By comparing the amount of Carbon-14 present in living tissue to the percentage of Carbon-14 remaining, the age of the previously living material can be determined.

Section 8.3   Practice

1. If a 4.0 gram sample of Carbon-14 has undergone decay for a period of three half-lives, how much Carbon-14 would remain?

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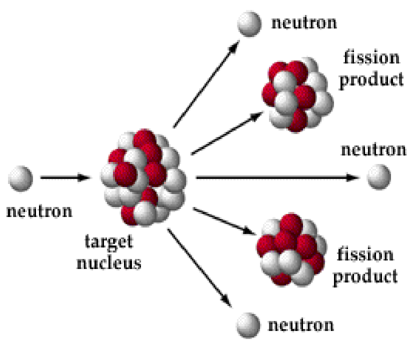
2. A doctor administers 12 mg Iodine-131 to a patient for a test. Assume the only way the patient gets rid of the radioactive material is through half-lives. The half-life of Iodine-131 is 8.07 days. How much Iodine remains after 24 days?

Section 8.4 Nuclear Fission and Nuclear Fusion

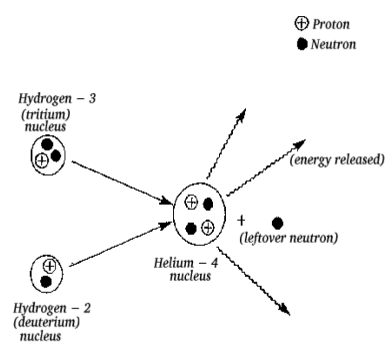
Nuclear fission is the splitting of the nucleus of an atom. Elements with atomic numbers greater than 90 undergo fission reactions. Uranium-235 undergoes nuclear fission when its nucleus absorbs an extra neutron. $^{235}_{92}U + ^{1}_{0}n \Rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3\,^{1}_{0}n$ + **energy**



In a fission reaction, the neutron splits the larger isotope into two smaller elements. There are three neutrons released which hit other target nuclei and keep the reaction going.

The three neutrons may be absorbed by other Uranium-235 nuclei and continue the reaction repeatedly. This is called a **nuclear chain reaction**. Tremendous amounts of energy are released. In a controlled nuclear fission reaction, excess neutrons are absorbed by other atoms and the release of energy is controlled. This is what occurs in nuclear reactors used in electrical generating plants. If the nuclear chain reaction is not controlled, the Uranium-235 is quickly used up and an enormous amount of energy is immediately unleashed. This happens in the explosion of an atomic bomb.

There is a tremendous amount of energy released in nuclear reactions. Albert Einstein developed the formula of $E = mc^2$ to explain where this energy comes from. In this formula, E equals energy, m equals mass and c equals the speed of light. Mass is converted to energy in these reactions.



Two Hydrogen nuclei are converted to Helium-4 in this fusion reaction.

In **nuclear fusion** reactions, nuclei of smaller atoms join together to form larger nuclei. Although fusion reactions are more difficult to start because a high temperature is required, the energy released in nuclear fusion reactions is even greater than nuclear fission. The energy from the sun and other stars is produced when Hydrogen atoms undergo nuclear fusion. The destructive power of Hydrogen bombs comes from nuclear fusion reactions. The fusion reaction is triggered by the explosion of a fission bomb, which provides the high temperature required for fusion to occur.

Section 8.4 Practice

1. How is a nuclear chain reaction maintained?

____

____

2. Compare and contrast nuclear fission with nuclear fusion.

____

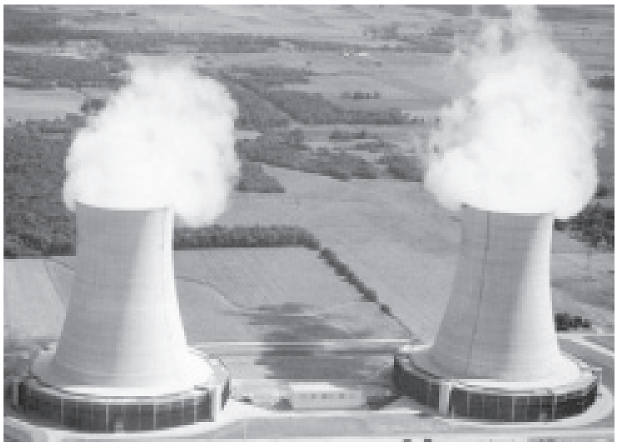
____

Section 8.5 Nuclear Energy

Nuclear power was first used to make the atomic bomb during World War II. Scientists bombarded Uranium-235 with a neutron which caused the splitting of the atom which released a great amount of energy.

$$^{235}_{92}U + ^{1}_{0}n \Rightarrow ^{140}_{56}Ba + ^{93}_{36}Kr + 3^{1}_{0}n + energy$$

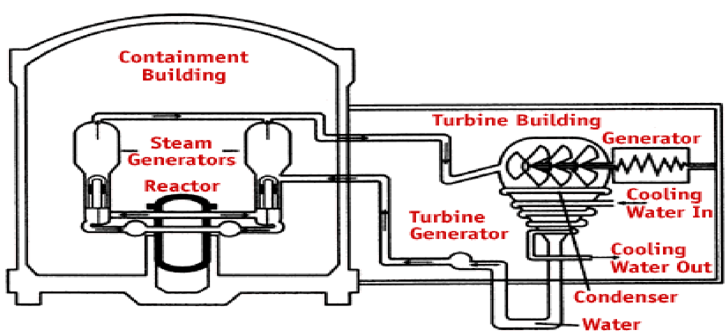
Albert Einstein discovered the reason that nuclear power releases so much energy in his famous equation, $E = mc^2$ (E = energy, m= mass, c = speed of light). A small amount of mass is converted to a great amount of energy.



Plant Vogtle in Waynesboro is a Nuclear Power Plant in Georgia.

Nuclear power plants were made to produce the Plutonium-239 needed to initiate the chain reaction needed for an atomic bomb. Nuclear power is also used in many submarines. Today, nuclear power plants produce some of our electricity in the United States and many other countries.

Nuclear power plants generate electricity by producing heat energy from nuclear fission reactions to boil water. The steam spins large generators producing electrical energy. Other plants that produce electricity, such as coal plants, use tons of coal to heat the water. There are concerns that we are running out of coal and then what will we do? On the other hand very little uranium is needed to power a nuclear power plant for electricity. It is enough fuel to for a chain reaction to continue but not enough for a nuclear explosion. Every reactor has control rods made of boron or cadmium to control the chain reaction. The nuclear fuel rods boil the water and the steam from the boiling water turns the turbines of the generator. Each nuclear power plant has a cooling tower to help cool the water after it has been used because there is so much heat energy generated in the reaction.



Nuclear power plants generate electricity through nuclear fission reactions.

There is nuclear waste from the used fuel rods that must be taken care of. Much of the spent fuel rods are stored in special surrounded by many feet of concrete at the nuclear reactor sites. Soil around the sites is always monitored to be sure no radioactive fuel leaks into the soil. A disposal waste site in Yucca Mountain, Nevada was created recently to store radioactive waste but the issue of transporting radioactive waste has been raised. Some people do not want trucks to carry the waste along US freeways to Nevada.

Section 8.5 Practice

1. In the space below, draw and label the parts of a nuclear reactor and nuclear power plant.

2. What are the advantages and disadvantages of nuclear power plants?

3. What is a chain reaction?

4. What radioactive material is contained in the fuel rods of a nuclear reactor?

CHAPTER REVIEW 8

A. Vocabulary

a.	alpha particle	h.	beta particle
b.	fission	i.	fusion
c.	gamma radiation	j.	half-life
d.	radioactivity	k.	electromagnetic radiation
e.	radioactive carbon dating	l.	radiation
f.	emitted	m.	radioisotope
g.	chain reaction		

_____1. the splitting of heavy atomic nuclei into lighter nuclei
_____2. the time needed for one half of the radioactive atoms in a sample to decay
_____3. particles and energy given off in a nuclear reaction
_____4. the particle given off in this nuclear reaction has the same atomic number and mass number as a helium atom
_____5. the particle in this nuclear reaction does not have mass or charge but can penetrate deeply and is held back by cement or a lead wall
_____6. the particle in this type of reaction has no mass and a negative charge like an electron
_____7. combining atomic nuclei with a release of energy
_____8. another term for the "giving off" of particles and energy
_____9. the spontaneous breakdown of the nucleus of an atom
_____10. elements with unstable nuclei
_____11. the process for calculating the age of a fossil
_____12. a sustained reaction that does not end until the fuel is removed
_____13. high energy waves such as X-ray and gamma radiation

B. Multiple Choice

_____1. A stable nucleus has which ratio of protons to neutrons?
- a. equal protons and neutrons
- b. more neutrons than protons
- c. more protons than neutrons
- d. no protons or neutrons

_____2. When an atomic nucleus splits into two smaller nuclei, it is called
- a. fission. b. fusion.
- c. radioisotopes. d. stable.

_____3. When an alpha radiation reaction occurs, an alpha particle is emitted. This particle is called a(n)
- a. electron. b. Helium nucleus.
- c. neutrino. d. beta particle.

_____4. Which of the following is most penetrating to human tissue?

a. Alpha particles b. Beta particles
c. Gamma rays d. Microwaves

_____5. What kind of radiation is given off in the following nuclear reaction?

$$^{226}_{88}Ra \Rightarrow ^{222}_{86}Ra$$

a. Alpha b. Beta
c. Gamma d. microwave

_____6. Background radiation is

a. found in your back yard only.
b. synthetic in nature.
c. natural exposure to radiation.
d. a dangerous exposure.

_____7. The source of energy produced by the sun is

a. burning fossil fuels. b. fission of Uranium.
c. fusion of Hydrogen. d. unknown.

_____8. In the famous equation $E = mc^2$, the symbol E represents

a. electricity. b. energy.
c. electrons. d. the speed of light.

_____9. Ionizing radiation is

a. radiation of sufficient energy to produce ions.
b. radiation of sufficient energy to remove electrons from atoms.
c. radiation of sufficient energy to provide charged atoms.
d. all of the above.

_____10. Which of the following isotopes would stand the greatest chance of being stable and not radioactive?

a. $^{203}_{82}Pb$ b. $^{14}_{6}C$
c. $^{16}_{7}N$ d. $^{16}_{8}O$

_____11. Which of the following is the least penetrating type of radiation?

a. Alpha b. Beta
c. Gamma d. X-ray

_____12. The half life of an isotope is the time required for half of the nuclei in a sample to undergo

a. fission. b. fusion
c. radioactive decay. d. a chemical reaction.

_____13. During radioactive decay, the nucleus of an isotope disintegrates into a

a. lighter and more stable nucleus.
b. lighter and less stable nucleus.
c. heavier and more stable nucleus.
d. heavier and less stable nucleus.

_____14. What does the **3** in $^{3}_{1}\mathbf{H}$ represent?

a. Atomic number b. Atomic mass
c. Number of neutrons d. Amount of radiation

_____15. The radioactive isotope used to date ancient remains is

a. Iodine-131. b. Iron-59.
c. Cobalt-60. d. Carbon-14.

_____16. Radioactive isotopes are used for all of the following except

a. smoke alarms. b. treating and detecting cancer.
c. air conditioners. d. killing bacteria in food.

_____17. A chain reaction occurs in

a. a chemical reaction. b. a physical change.
c. a nuclear reaction. d. all reactions.

_____18. What types of radiation are shown in the following equation?

$$^{238}_{92}U \Rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + {}^{0}_{0}\gamma$$

a. Alpha and Beta b. Alpha and Gamma
c. Beta and Gamma d. Alpha, Beta and Gamma

_____19. Which radiation is the most dangerous if it could get inside our body?

a. Alpha b. Beta
c. Gamma d. Microwave

_____20. Why do we wear lead aprons when we get X-rays?

a. The lead in the apron helps to make a clearer picture.
b. The lead in the apron contains the X-rays needed to get the picture.
c. It decreases the power of the radiation in the X-ray.
d. It stops the radiation from entering the body.

C. Activities

Activity 1. Nuclear Energy Debate

Georgia Performance Standards:

SCSh1. Students will evaluate the importance of curiosity, honesty, openness and skepticism in science.
b. Recognize that different explanations often can be given for the same evidence.
SCSh6. Students will communicate scientific investigations and information clearly.
b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.
SCSh9. Students will enhance reading in all curriculum areas by:
d. Explore life experience related to subject area context.

Use the Internet to research the advantages and disadvantages of nuclear energy. Your class will be divided into two sides–pro and con.

• Make a poster or write a report to represent your side. Create a rubric with your teacher's guidance that will establish the criteria for the poster or the report. Make sure that your poster meets all of the criteria for evaluation.

• Debate the pros and cons of nuclear power with your classmates. Each side should develop three supporting arguments either for or against nuclear power and then find three current pieces of scientific evidence that back up each supporting argument. Stage the debate during class and have community volunteers judge the debate.

Activity 2. Nuclear Power Production

Georgia Performance Standards:

SCSh1. Students will evaluate the importance of curiosity, honesty, openness and skepticism in science.
b. Recognize that different explanations often can be given for the same evidence.
SCSh6. Students will communicate scientific investigations and information clearly.
b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.
SCSh9. Students will enhance reading in all curriculum areas by:
d. Explore life experience related to subject area context.

Use the Internet to discover the amount of electricity produced by nuclear power plants in the U.S. and other countries.

Questions:
1. Who uses the most nuclear energy to obtain electricity?
2. Based on the world's growing need for electricity, what changes do you predict will happen to nuclear production in the future?
3. How will the growth or decline of nuclear power impact other sources of energy, such as coal and gas?

Activity 3. Nuclear Accidents

Georgia Performance Standards:

SCSh1. Students will evaluate the importance of curiosity, honesty, openness and skepticism in science.
b. Recognize that different explanations often can be given for the same evidence.
SCSh6. Students will communicate scientific investigations and information clearly.
b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.
SCSh9. Students will enhance reading in all curriculum areas by:
d. Explore life experience related to subject area context.

Investigate radioactive leaks at Three Mile Island, Pennsylvania and Chernobyl, Ukraine. Make a chart to compare and contrast the two nuclear reactor sites based on the following criteria:

a. Types of reactors
b. Causes of leaks
c. Safety systems of each plant
d. Long-term effects of the radiation leaks
e. Impact on nuclear power production in respective country