Period 9Activity Solutions: Ionizing Radiation

9.1 What is Ionizing Radiation?

Your instructor will discuss ionizing radiation.

1) Defining ionizing radiation

How does ionizing radiation differ from other types of radiation, such as microwaves, infrared radiation, or visible light?

Radiation is a general term that refers to anything, such as energy or particles, that radiates outward from source. Ionizing radiation is radiation that causes atoms in its path to be ionized, or stripped of one or more electrons. Ionizing radiation can be particularly damaging to living things.

2) Types of ionizing radiation

a) What is an alpha particle (α) composed of? What is the electric charge of an alpha particle?

An alpha particle is made up of a helium nuclei – 2 protons and 2 electrons ($^{4}_{2}He$). Since an alpha particle has two protons, it has a charge of +2.

b) What are the two types of beta particles (β) composed of? What is the electric charge of each type of beta particle?

A beta particle can be made of an electron (β^-) and have an electric charge of –1. A beta particle can also be made of an antielectron (β^+), which is also called a positron. An antielectron is an electron with a positive charge, so an antielectron has a charge of +1.

c) What is a gamma particle (γ) composed of? Do gamma particles have an electric charge?

Gamma particles are photons of high energy electromagnetic radiation. Gamma particles have no electric charge.

d) Which type of electromagnetic radiation has the most ionizing ability? Why?

Alpha particles have the most ionizing ability. Since each alpha particle has two electric charges, each particle can ionize two atoms.

9.2 How is Ionizing Radiation Detected?

3) Detecting ionizing radiation

Your instructor will show you how to operate the Geiger counters and the timers.

a) Perform a count of background radiation in the room by counting the number of clicks (events) every minute. What is the background level of counts/minute?

The background level is usually about 25 to 30 counts per minute.

b) What is the source of this background radiation?

Naturally-occurring radioactive particles in building materials and cosmic rays from outer space.

4) The strength of ionizing radiation

Your instructor will bring you a weak radioactive source. Attach the Geiger counter detector to a ring stand. Place the source 10 cm from the open side of the detector and record the number of counts per minute.

a) How many counts per minute result from this source? ______________

b) Place the source 20 cm from the detector and record the number of counts per minute. _______________

c) Place the source 40 cm from the detector and record the number of counts per minute. _______________

d) What effect does increasing the distance have on the count?

The number of counts decreases as the distance from the detector increases.

5) The Penetrating ability of ionizing radiation

Your instructor will give you three weak radioactive sources that emit alpha, beta, or gamma particles. Test the penetrating ability of each type of ionizing radiation by placing the sources, one at a time, approximate 10 cm from the open side of the Geiger counter detector. Try shielding each source with pieces of cardboard, aluminum, and lead. Write “yes” or “no” in the table below to indicate which materials shielded each source.

Does the shielding material significantly reduce the ionizing radiation recorded by the Geiger counter?

Shielding material	alpha	beta	gamma
a) cardboard	**yes**	**no**	**no**
b) one aluminum sheet	**yes**	**no**	**no**
c) multiple aluminum sheets	**yes**	**partially**	**no**
d) one lead sheet	**yes**	**yes**	**no**
e) multiple lead sheets	**yes**	**yes**	**partially**

9.3 Why Do Nuclei Decay?

6) Source of ionizing radiation

What is the source of ionizing radiation?

Materials containing atoms with unstable nuclei are radioactive. As the nuclei decay, they give off ionizing radiation – some combination of alpha, beta, or gamma radiation, depending on the nuclear reaction.

7) Unstable large nuclei

a) Why are large nuclei with more than 82 protons unstable?

The strong nuclear force that binds the nucleus operates over a very short distance. In large nuclei, the strong force cannot bind the nucleons tightly enough to overcome the repulsive electromagnetic force between the positively charged protons.

b) Which type of radioactive decay (α, β, or γ) would reduce the size of a nucleus?

Alpha decay emits a helium nuclei ($^{4}_{2}He$). The nucleus is reduced in size by two protons and two neutrons.

c) What happens to the identity of the nucleus after this type of decay?

Since the nucleus loses two protons, we now have a nucleus of a different element – an element with two fewer protons than the original nucleus.

8) Unstable small nuclei

a) Why are some isotopes of small nuclei unstable?

Most isotopes of small nuclei (20 or fewer protons) that have unequal numbers of protons and neutrons are unstable.

b) Which type of radioactive decay (α, β, or γ) would make such isotopes more stable?

Beta decay makes an isotope more stable by changing the electric charge of the nucleus. The nucleus charge is increased by 1 when an electron (β^-) is emitted. In this case, one neutron is changed into a proton. The nucleus charge is decreased by 1 when an antielectron (β^+) is emitted. In this case, one proton is changed into a neutron.

c) What happens to the identity of the nucleus after this type of decay?

Since the number of protons changes, the nucleus changes into a nucleus of a different element.

d) What happens to the total number of nucleons after this type of decay?

The total number of nucleons is unchanged.

9) Neutrinos

a) What is a neutrino?

Neutrinos are very light neutral particles emitted during beta decay.

b) Which type of neutrino is emitted when an electron (β^-) is emitted?

An antineutrino ($\bar{\nu}$) is emitted when an electron is emitted.

c) Write the equation for the nuclear reaction that occurs when a neutron emits an electron and becomes a proton.

$$ {}^{1}_{0}\mathbf{n} \rightarrow {}^{1}_{1}\mathbf{p} + {}^{0}_{-1}\mathbf{e} + {}^{0}_{0}\bar{\nu}, $$ **where $\bar{\nu}$ denotes an antineutrino**

d) Which type of neutrino is emitted when an antielectron (β^+) is emitted?

A neutrino (ν) is emitted when an antielectron is emitted.

e) Write the equation for the nuclear reaction that occurs when a proton emits an antielectron and becomes a neutron.

$$ {}^{1}_{1}\mathbf{p} \rightarrow {}^{1}_{0}\mathbf{n} + {}^{0}_{1}\mathbf{e} + {}^{0}_{0}\nu $$ **where ν denotes a neutrino**

9.4 How do Unstable Nuclei Decay?

10) Conservation laws

a) What is conservation of charge? How does this conservation law apply to a nuclear reaction?

Conservation of charge tells us that electric charge cannot be created or destroyed. In a nuclear or a chemical reaction, the net electric charge of the reactants must equal the net charge of the products.

b) What is conservation of nucleon number? How does this conservation law apply to a nuclear reaction?

Conservation of nucleon number tells us that the total number of nucleons in a nuclear reaction does not change. While protons can be converted into neutrons, or neutrons into protons, the total number of neutrons plus protons does not change during a nuclear reaction.

11) Nuclear decay

Fill in the table below, which summarizes the properties of the types of ionizing radiation.

Radiation	**Particle emitted**	**A = # of nucleons**	**Z = # of protons**	**Electric Charge**
alpha (α)	**helium nuclei ($^{4}_{2}He$)**	**4**	**2**	**+2**
	electron (e^{-})	**0**	**0**	**-1**
beta (β^{+})	**antielectron (e^{+})**	**0**	**0**	**+1**
gamma (γ)	**high energy photon**	**0**	**0**	**0**

12) Nuclear reactions

Use the conservation laws and the information in the nuclear decay table to answer the questions below.

a) In a nuclear reaction, potassium-40 ($^{40}_{19}K$) decays by emitting one electron. Write an equation that describes this nuclear reaction.

$$^{40}_{19}K \rightarrow \,^{40}_{20}Ca + \,^{0}_{-1}e + \,^{0}_{0}\bar{\nu}$$

b) Thorium-232 ($^{232}_{90}Th$) decays into radon-228 ($^{228}_{88}Ra$) and emits a particle of ionizing radiation. Write an equation that describes this nuclear reaction.

$$^{232}_{90}Th \rightarrow \,^{228}_{88}Ra + \,^{4}_{2}He$$

c) Uranium-238 decays by emitting an alpha particle. Write an equation that describes this reaction. Which element is formed after this decay?

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

The periodic chart shows that the element with 90 protons (Z = 90) is thorium (Th).