

Name: _____ Section: _____

Activity 10: Ionizing Radiation I

10.1 What is Ionizing Radiation?

1) Stable and Unstable Nuclei

- a) Watch the demonstration of isotopes placed near a Geiger counter. Geiger counter clicks indicate unstable nuclei. Record the results of the experiment.

Isotope	Geiger counter clicks?	Stable or Unstable?
$^{238}_{92}\text{U}$ (uranium-238)	_____	_____
$^{207}_{82}\text{Pb}$ (lead-207)	_____	_____
$^{26}_{13}\text{Al}$ (aluminum-26)	_____	_____
$^{226}_{88}\text{Ra}$ (radium-226)	_____	_____

- b) The Geiger counter clicks when it detects ionizing radiation. Which of these isotopes are radioactive? _____
- c) Why are unstable nuclei radioactive?

2) Ionizing radiation

- a) What is an alpha particle (α)? What is the electric charge of an alpha particle?
- b) What are the two types of beta particles (β)? What is the electric charge of each type of beta particle?
- c) What is a gamma particle (γ)? Do gamma particles have an electric charge?

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

e) Which type of ionizing radiation has the least ionizing ability? Why?

3) Summary of Ionizing Radiation

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)				
beta (β^-)				
beta (β^+)				
gamma (γ)				

4) Radioactive decay of large unstable nuclei

a) Why are large nuclei with more than 83 protons unstable?

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

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

5) Radioactive decay of small unstable nuclei

a) Why are some isotopes of small nuclei unstable?

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

c) Group Discussion Question: Which types of decay (alpha, beta plus, beta minus, or gamma) result in the formation of nuclei of a different element?

6) Ionizing radiation in a cloud chamber

Your instructor will show you radiation events in a cloud chamber.

- a) How does a cloud chamber detect radiation? Why are alcohol and the dry ice needed?

- b) How do the trails of alpha particles compare with those of beta particles? Why?

10.2 How do Unstable Nuclei Decay?

7) Conservation laws

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

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

- c) The radioactive isotope thorium-232 (${}_{90}^{232}\text{Th}$) decays into radon-228 (${}_{88}^{228}\text{Ra}$) and emits a particle of ionizing radiation.
 - i) Write an equation that describes this nuclear reaction.

 - ii) Which ionizing particle is emitted? _____

- d) Uranium-238 decays by emitting an alpha particle.
 - i) Write an equation that describes this reaction.

 - ii) Which element is formed after this decay?

8) Neutrinos and Conservation of Energy and

- a) What is conservation of energy?

- b) The electrons and antielectrons (β^- and β^+) emitted during beta decay of a particular isotope have varying amounts of energy. How does the cloud chamber image show this?

- c) Beta particles from the decay of identical nuclei can have varying amounts of energy. To preserve conservation of energy, a beta decay reaction must emit another type of particle called a neutrino (ν).

What is a neutrino? Does a neutrino have an electric charge?

10.3 Examples of Radioactive Decay

9) **Beta Plus Decay (β^+)** Using plastic chips, make up a nucleus of protons and neutrons. The white sides of the chips represent neutrons and the orange sides represent protons. Turn a chip from its orange side to its white side to represent a proton changing into a neutron. Then open the box marked "beta plus decay" to see the products of this reaction.

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

- b) Why is an antielectron, rather than an electron, emitted in this reaction?

- c) What does the spring represent?

10) Conservation of Leptons and Antineutrinos

- a) Leptons are light-weight particles, such as electrons and neutrinos. What is conservation of leptons?

i) When an antielectron is emitted, is a neutrino (ν) or an antineutrino ($\bar{\nu}$) emitted?

ii) When an electron is emitted, is a neutrino or an antineutrino emitted?

11) Beta Minus Decay (β^-) Turn a chip in your nucleus from its white side to its orange side to represent a neutron changing into a proton. Then open the box marked "beta minus decay" to see the products of this reaction.

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

b) Why is an electron, rather than an antielectron, emitted in this reaction?

c) Why is an antineutrino, rather than a neutrino, emitted?

12) Gamma Decay (γ) Some unstable nuclei emit gamma particles. Open the box marked "gamma decay" to see what a gamma particle is.

a) What is a gamma particle?

b) What is the charge of a gamma particle? What is its mass?

c) Why do nuclei emit gamma particles?

13) Examples of Nuclear Reactions

a) Oxygen-14 ($^{14}_8\text{O}$) is an unstable isotope of oxygen. Arrange orange and white plastic chips to represent this isotope. Draw a diagram of your arrangement.

- b) Why is this isotope unstable?
- c) How would $^{14}_8\text{O}$ decay to become stable? Change the plastic chips and open the appropriate box to illustrate this decay. What change to the chips did you make? Which box did you open?
- d) Is the decay product an isotope of oxygen? If not, what element has the nucleus become?
- e) In part c), you turned over an orange chip to its white side to represent a proton changing into a neutron. Rearrange these chips so that the orange chips (protons) are separated from one another as much as possible by white chips (neutrons). Rearranging the chips (nucleons) is a transition accompanied by the emission of which type of ionizing radiation – alpha, beta, or gamma?

10.4 What Is the Composition of a Nucleon?

Your instructor will discuss the composition of nucleons, which consist of quark trios held together by gluon clouds.

14) Quarks

- a) What is a quark?
- i) What is the electric charge of an "up" quark? _____
- ii) What is the electric charge of a "down" quark? _____
- b) What is the spin of a quark?
- c) Place two of the green model "down" quarks side by side. In which directions do the spins of two quarks point?

15) Formation of Neutrons

Place orange or green "quarks" into the metal "gluon cloud" to represent a neutron. (Hint: what is the electric charge of a neutron?)

a) Draw a diagram showing the quarks in the neutron.

b) Each quark has a spin of $\frac{1}{2}$. What is the total spin of a neutron? _____

c) Why does this arrangement of the 3 quarks result in a spin of $\frac{1}{2}$ for the neutron?

16) Formation of Protons

Place orange or green "quarks" into the metal "gluon cloud" to represent a proton. Make sure the spin of the proton points in the same direction as the spin of the neutron in part a). (You may need to rotate the metal gluon cloud.)

a) Draw a diagram showing the quarks in the proton.

b) What is the total spin of a proton? _____

c) Why does this arrangement of the 3 quarks result in a spin of $\frac{1}{2}$ for the proton?

d) Which of the four fundamental forces is involved in binding quarks into nucleons?

e) The exchange of which type of gauge boson is responsible for binding quarks into nucleons?

f) Group Discussion Question: How is the gluon cloud model of a nucleon related to flipping an orange or a white chip?

