Preview of Period 10:

10.1 Ionizing Radiation

What types of particles are emitted when radioactive atoms decay?

10.2 How is Ionizing Radiation Detected?

Why does the Geiger counter measure counts when no radioactive source is placed nearby?

10.3 Nuclear Decay

Why do some nuclei decay and other nuclei do not?

10.4 How do Nuclei Decay?

Which conservation laws govern nuclear decay?

10.5 What is the Standard Model of Particle Physics?

What is the composition of fundamental particles?

How are fundamental particles bound together?

Which nuclei are stable?

Stable nuclei have

- 83 or fewer protons.
- the same number of protons and neutrons for light elements with 20 or fewer protons.
- more neutrons than protons for elements with more than 20 protons.

What happens to unstable nuclei?

Unstable nuclei become more stable by changing protons into neutrons or neutrons into protons.

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

Ionizing Radiation

Radiation refers to anything radiates outward from a source. (Example: electromagnetic radiation – radio waves, microwaves, infrared radiation, visible light, etc.)

Ionizing radiation is radiation that strips electrons from atoms, turning the atoms into charged ions.

Unstable nuclei can give off these types of ionizing radiation:

- Alpha particles α are helium nuclei $^{4}_{2}He$ (2 neutrons and 2 protons)
- Beta particles are β^- electrons $^{0}_{-1}e$

  or β^+ antielectrons $^{0}_{+1}e$
- Gamma particles γ are very high energy photons.

Summary of Ionizing Radiation

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

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gamma γ	high energy photon			

The Cloud Chamber

- **Alcohol vapor in the cloud chamber is cooled by dry ice (frozen carbon dioxide).**
- **The alcohol temperature is slightly below the temperature at which it would normally condense into droplets. (The vapor is supercooled.)**
- **Ions are produced along the paths of the particles that result from the decay of the radioactive sources.**
- **These ions seed the supercooled vapor and form tiny raindrops around the ions, leaving visible tracks.**
- **The tracks can also reveal the ionization density of the source, since some tracks appear thicker (more droplets) than others.**

Conservation Law and Nuclear Reactions

Apply conservation of charge and conservation of nucleon number to determine the decay products of a nuclear reaction:

> **Charge must be conserved so that the number of positive or negative charges (Z) on each side of the reaction is equal.**
>
> **Nucleon number must be conserved so that the number of nucleons (A) on each side of the reaction is equal.**

Use conservation of electric charge and conservation of nucleon number to find the decay products.

$$^{232}_{90}\mathrm{Th} \rightarrow \, ^{228}_{88}\mathrm{Ra} + \, ^{A}_{Z}\mathrm{X}$$

$$^{238}_{92}\mathrm{U} \rightarrow \, ^{4}_{2}\mathrm{He} + \, ^{A}_{Z}\mathrm{X}$$

Conservation of Energy: Neutrinos

Conservation of Energy means that the energy of reaction products must equal the energy of the reactants.

Particles called neutrinos (ν) or antineutrinos ($\bar{\nu}$) are emitted in beta decays so that the energy of the reaction products equals the energy of the reactants.

Neutrinos have no charge and very little, if any, mass.

In a beta decay, a neutrino is also emitted.

β^+ decay: A proton changes into a neutron by emitting an antielectron and a neutrino.

$$ {}^{1}_{1}\mathbf{p} \rightarrow {}^{1}_{0}\mathbf{n} + {}^{0}_{+1}\mathbf{e}^{+} + {}^{0}_{0}\nu + \textbf{energy} $$

Conservation of Leptons: Neutrinos and Antineutrios

Electrons and neutrinos are examples of leptons. Whenever a lepton is emitted, an antilepton must also be emitted.

- An antineutrino $\overline{\nu}$ is emitted with an electron
- A neutrino ν is emitted with an antielectron.

β^- decay: A neutron changes into a proton by emitting an electron and an antineutrino.

$$ {}^{1}_{0}\mathbf{n} \rightarrow {}^{1}_{1}\mathbf{p} + {}^{0}_{-1}\mathbf{e}^{-} + {}^{0}_{0}\overline{\nu} + \mathbf{energy} $$

Use conservation of electric charge, nucleon number and leptons to find the decay products.

$$ {}^{40}_{19}\mathbf{K} \rightarrow {}^{0}_{-1}\mathbf{e} + {}^{0}_{0}\mathbf{?} + {}^{A}_{Z}\mathbf{X} $$

Stable Fundamental Particles and Quarks

The electron is a fundamental particle.

Neutrons and protons are made up of fundamental particles called quarks.

The Standard Model of Particle Physics attempts to explain the fundamental particles and how they are related to one another.

These relationships involve the strong nuclear, weak nuclear, and electromagnetic forces.

Quarks

Electric Charge	1st generation particle	2nd generation particle	3rd generation particle
+2/3	**u** up quark	**c** charm quark	**t** top quark
− 1/3	**d** down quark	**s** strange quark	**b** bottom quark

Quarks have electric charge as shown in the table.

Quarks, like many other particles, have a rotation about their axes called intrinsic spin. The intrinsic spin of quarks = ½

Guidelines for combining quark trios into nucleons:

1. Find a combination of quarks whose electric charge equals the charge of the nucleon. (up quark = + 2/3; down quark = - 1/3)

2. For two quarks of the same type (2 up quarks or 2 down quarks), the spins must point in opposite directions.

   Note: Depending on how the quarks are combined, the spin of the nucleon formed from the quarks will point either up or down.

Forces Binding Quark Trios into Nucleons

The strong nuclear, weak nuclear, and electromagnetic forces arise from the exchange of carrier particles known as gauge bosons.

The gluon (g) is the gauge boson responsible for the strong nuclear force that holds three quarks together to form a neutron or a proton.

The gamma boson is the boson responsible for the boson exchange in electromagnetic force.

The pion, composed of a quark and an antiquark, is responsible for binding the protons and neutrons together in an atomic nucleus.

Period 10 Summary

10.1&2 Ionizing radiation strips electrons from atoms, turning the atoms into charged ions.

Unstable nuclei decay by giving off alpha, beta, or gamma particles.

Alpha particles (α) are helium nuclei $^{4}_{2}He$

Beta particles are β^- (electrons $^{0}_{-1}e$) or β^+ (antielectrons $^{0}_{+1}e$)

Gamma particles (γ) are high energy photons.

10.3 In beta decay, a neutrino is also emitted.

An antineutrino is emitted with an electron, and a neutrino is emitted with an antielectron

A proton can change into a neutron by emitting an antielectron and a neutrino.

$$^{1}_{1}p \rightarrow \, ^{1}_{0}n + \, ^{0}_{+1}e^{+} + \, ^{0}_{0}\nu$$

A neutron can change into a proton by emitting an electron and an antineutrino.

$$^{1}_{0}n \rightarrow \, ^{1}_{1}p + \, ^{0}_{-1}e^{-} + \, ^{0}_{0}\bar{\nu}$$

In nuclear reactions, charge (Z), nucleon number (A), energy, and lepton number are conserved. (Leptons are fundamental particles, such as electrons and neutrinos.)

10.4 The Standard Model of particle physics attempts to explain the fundamental particles and how they combine.

The electron is a fundamental particle, but neutrons and protons are made up of fundamental particles called quarks.

The electric charge of an up quark = + 2/3, and the charge of a down quark = - 1/3.

To form a proton (charge = +1), two up quarks combine with one down quark.

To form a neutron (charge = 0), one up quark combines with two down quarks.

Almost all particles in physics have a rotation about their axes called intrinsic spin. The intrinsic spin of quarks and leptons = ½

When 3 quarks combine to form a proton, the spins of the two up quarks point in opposite directions. The total spin of the proton is ½ – ½ + ½ = ½.

The strong nuclear, weak nuclear, and electromagnetic forces arise from the exchange of carrier particles known as gauge bosons.

The gluon (g) is the gauge boson responsible for the strong nuclear force that holds three quarks together to form a neutron or a proton.

Period 10 Review Questions

R.1 **What is the source of ionizing radiation? How does ionizing radiation differ from other types of radiation?**

R.2 **How does a cloud chamber work? How can you tell the difference between the tracks of alpha and beta particles in a cloud chamber?**

R.3 **What are neutrinos and antineutrinos? When are they produced?**

R.4 **What are the fundamental particles from which all matter is built? How could these particles be arranged to form a proton?**

R.5 **What is the spin of fundamental particles? How could the spins of the fundamental particles making up a proton be arranged?**

R.6 Fill in the chart with the characteristics of ionizing radiation.

Particle	What is it?	Charge	Ionizing density	Penetrating ability
alpha α				
beta β^-				
beta β^+				
gamma γ				