lesson plan

It's All Greek to Me: Radioactive Decay

What happens to the nucleus of a radioisotope as it decays?

overview

LESSON CONTEXT

Elements on the periodic table with atomic numbers greater than 83 have no stable isotopes. The nuclei of these elements spontaneously disintegrate in a process called radioactivity. When a nucleus disintegrates, it can emit alpha particles, beta particles and gamma rays.

LEARNING GOALS

- Understand the processes of alpha decay, beta decay and gamma ray production.
- Complete nuclear decay equations.
- Determine the decay series of uranium-238.

LEARNING ACTIVITIES

In this lesson, students will learn about this disintegration or 'decay' process. The students will work with nuclear decay equations and will determine the decay series of uranium-238.

BIG IDEAS

In the process of radioactive decay, a radioisotope (parent) changes into other isotopes called progeny (formerly called daughters) which may either be radioactive or stable through either alpha decay or beta decay.

time
60-75
MINUTES

subjects
SCIENCE
PHYSICS

skills
COLLABORATION
COMMUNICATION

assessment & evaluation

PRIOR KNOWLEDGE AND SKILLS

- Basic understanding of isotopes and radioisotopes
- Familiarity with the atom and its basic structure
- Experience working in cooperative small groups

SUCCESS CRITERIA

- Students participate meaningfully in class discussions
- Students demonstrate understanding of nuclear decay processes

ASSESSMENT STRATEGIES

- Review of **Nuclear Decay Reactions Cut & Paste BLM**
- Review of **Nuclear Decay Reactions Self-Assessment BLM**

resources & materials required

- PPT **Radioactive Decay PowerPoint**
- DOC PDF **BLM – Nuclear Decay Reactions Cut & Paste** – one per pair of students
- DOC PDF **BLM – Nuclear Decay Reactions Self-Assessment** – one per student
- DOC PDF **BLM – Uranium-238 Decay Series** – one per pair of students
- DOC PDF **BLM – Alpha and Beta Decay Info Sheet** – one per pair of students
- DOC PDF **BLM – Gamma Rays Info Sheet** – one per pair of students
- PDF **BLM – Nuclear Decay Reactions Cut & Paste Answer Page** – for teacher use
- PDF Curriculum alignment
- Student notebooks
- Scissors – one per student
- Glue – one per pair of students
- Periodic table – one per pair of students
- Transparent tape – one roll per pair of students
- Electronic device with internet access

minds-on

30 MINUTES

- To begin the lesson, have students view the **Radioactive Decay PowerPoint**. Encourage students to take notes in their science journals during the slide show.
- In this PowerPoint the students will review the structure of the atom (nucleus, protons, neutrons and electrons), Standard Atomic Notation (SAN) and isotopes.
- The students will then be introduced to unstable nuclei and radioactivity (spontaneous disintegration of a nucleus) and the fact that when a nucleus disintegrates, it can potentially emit:
  - » alpha particles;
  - » beta particles; or
  - » gamma rays.
- Discuss the characteristics of alpha particles and the process of alpha decay using slides 11 and 12 of the PowerPoint (also see the **Did You Know?** below).

DID YOU KNOW?

Alpha Particles

- Given the Greek symbol for alpha, α (first letter of the Greek alphabet)
- Fast moving, high energy
- Relatively heavy, lose energy quickly
- Travel 2.5 cm in air, stopped by a piece of paper
- Penetrate skin only 0.3 mm
- Rutherford found an alpha particle to be the nucleus of a helium atom

Alpha Decay

- When an unstable nucleus emits an alpha particle it undergoes alpha decay
- The resulting new nucleus is an isotope of a different element

An example of alpha decay is:

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

- Uranium-238 undergoes alpha decay and becomes an isotope of thorium
- The conservation of mass holds (no particles are destroyed)

- Discuss, using slides 13 to 15, the characteristics of beta particles and the process of beta negative and beta positive decay (see the **Did You Know?** below).
- For more information on alpha and beta particles and decay, see the **Alpha and Beta Decay Info Sheet BLM**.
- Next, discuss gamma rays using slide 16 of the **Radioactive Decay PowerPoint**. For more information on gamma rays, see the **Gamma Rays Info Sheet BLM**. Some of the nuclear reactions in the uranium-238 decay series emit gamma rays.
- Finally, review slide 17 of the PowerPoint, which discusses nuclear reactions and demonstrates the method for writing nuclear equations. The students will use this method to complete the questions on the **Nuclear Decay Reactions Cut & Paste BLM**.

IMPLEMENTATION OPTIONS

- It would be beneficial for students to complete the **Understanding Isotopes** lesson and the **Radioactive Half-Life: The Whole Story** lesson before this lesson to establish prior knowledge or review concepts.
- Students could also be provided with the PowerPoint presentation to review additional times after class.

DID YOU KNOW?

Beta Particles

- Given the Greek symbol for beta, β (second letter of the Greek alphabet)
- Very light, very fast
- Can travel 4.5 m in air*, penetrate skin 17 mm *(depends on their initial energy because their velocities can range from zero to an upper limit depending on the radionuclide)
- Stopped with 0.1 mm of lead
- Beta particles are electrons or positrons

Beta Decay

- The production of beta particles is known as beta decay. Two types of beta decay are known: β– decay and β+ decay

β– Decay

- Neutron in the nucleus of an unstable atom is converted into a proton
- Atomic number goes up by one (new element)
- When a neutron decays the beta particles emitted are electrons (negative charge)

$^{0}_{-1}e$

- Antineutrinos also released
- Also known as electron emission

$\overline{\nu}$

An example of β– is:

$^{210}_{82}Pb \rightarrow {}^{210}_{83}Bi + {}^{0}_{-1}e + \overline{\nu}$

β+ Decay

- Proton in the nucleus of an unstable atom is converted into a neutron
- Atomic number goes down by one (new element)
- When a neutron decays the beta particles emitted are positrons (positive charge)

$^{0}_{1}e$

- Neutrinos are also released
- Also known as positron emission

ν

An example of β+ is

$^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{1}e + \nu$

action

15 MINUTES PLUS RESEARCH TIME OUTSIDE CLASS

- Distribute the **Nuclear Decay Reactions Cut & Paste BLM** and a periodic table to each pair of students. Each pair of students will work together to cut out and paste the correct nuclear particles or symbols from page three of the BLM onto the squares on pages one and two of the BLM.
- Merge pairs to form groups of four and have each group compare answers. Finally, merge the class to review the answers.
- Explain to the students that the nuclear reactions that they just completed are actually the nuclear reactions that make up the uranium-238 decay series. Uranium-238 is a well-known naturally occurring radioactive element which is one of the most abundant elements found in the Earth's crust. It can be found almost everywhere – in soil and rock, in rivers, and oceans; traces of uranium are even found in food and human tissue. In its attempt to become a stable element, the radioisotope uranium-238 undergoes a series of 14 radioactive decays until it eventually becomes lead-206, a stable non-radioactive element.
- Explain to the students that the reactions on their **Nuclear Decay Reactions Cut & Paste BLM** are not in order. Their task is to cut out the reactions along the dashed lines, then complete the decay reactions and put them in order beginning at uranium-238 and ending at lead-206.
- Once the students have completed what they believe is the correct sequence, hand out the **Uranium-238 Decay Series BLM** so that students may check the order and rearrange as necessary. Once the reactions are in the correct order, have the students tape the strips together to make one large chart. If you choose not to have students cut and paste the symbols, they could simply refer to page three of the BLM and write the correct nuclear particles or symbols in the boxes.

consolidation

20 MINUTES

- Have a consolidating discussion with the class. Questions to consider for class discussion include:
  - » *In your own words, how would you explain alpha decay, beta decay and gamma rays?*
  - » *Other than the number of protons and neutrons involved, what are some other differences between alpha and beta decay?*
  - » *Why does the atomic mass of an atom change during alpha decay but not during beta decay?*
  - » *Is there any way an atom could experience a series of alpha and beta decays and eventually return to its original state? Explain why this could or could not occur.*
- In addition to having a class discussion to consolidate understanding, students could complete the **Nuclear Decay Reactions Self-Assessment BLM**.

DID YOU KNOW?

Gamma Rays

- Given the Greek symbol for gamma, γ (third letter of the Greek alphabet)
- Travels 2 km in air
- Can pass through 10 cm of lead
- Type of ionizing electromagnetic radiation
- Highest frequency and shortest wavelength in the electromagnetic spectrum
- A gamma ray is a photon and is given the symbol, ${}^{0}_{0}\gamma$ or simply γ when used in nuclear reactions

Gamma Ray Production

- After a nucleus undergoes alpha or beta decay, the nucleus created is often left in an excited state
- An excited nucleus is written as follows, ${}^{192}_{77}Ir^{*}$ The star denotes that the atom is in an excited state
- A gamma ray is discharged to return the nucleus to the ground state

extensions

- Students could create posters of one of the other natural decay series, such as the thorium-232 series, the neptunium-237 series or the uranium-235 series, identifying all of the nuclear reactions in the series.
- Students could research some of the practical applications of radioactive isotopes which emit alpha and beta particles (see the **Alpha and Beta Decay Info Sheet BLM**) as well as gamma rays (see the **Gamma Ray Info Sheet BLM**).

additional resources

CANADIAN NUCLEAR ASSOCIATION WEB PAGES

- **What is radiation?**
- **Quantifying radiation**

RELATED TEACHNUCLEAR LESSON PLANS

- **Attack of the 50 Foot Mutant: Radiation in Popular Culture**
- **From the Outside In: Biological Effects of Radiation**
- **Radioactive Half-Life: The Whole Story**
- **Understanding Isotopes**

background information

(Retrieved August 2019)

- **Glossary – Jefferson Lab, U.S. Department of Energy**
  A glossary of nuclear-related terms including definitions and diagrams of alpha decay, beta decay, alpha particles and beta particles.
- **Energy From Uranium – The NEED Project**
  Hands-on, multidisciplinary activities that introduce students to the chemistry and physics of uranium, the process of fission, history of nuclear science, and the role of uranium in electricity generation.
- **The Timeline of Radioactive Decay of Uranium-238 (U238) – The Institution of Engineering and Technology**
  This fact sheet details the decay process of uranium-238. It includes the type of radiation (a, b, γ), as well as the half-life of each isotope.
- **Lesson #43: Alpha, Beta, & Gamma Decay – Mr. Clintberg's Studyphysics!**
  A lesson on alpha, beta and gamma decay.
- **Radiation Protection – United States Environmental Protection Agency**
  Information about how to protect yourself against radiation and a dose calculator to estimate your yearly dose of ionizing radiation.
- **Radioactive decay – BBC Bitesize Science**
  Information about radioactive decay and nuclear radiation.