

Activity 6: Radioactive Decay Chain

Objectives

Students will:

- Learn about radioactive decay and decay chains.
- Observe a decay chain.
- Identify types of radiation emitted with each step in the decay chain.

NOTE: Students should be familiar with atomic structure and the concept of radioactivity prior to completing this activity. The information presented in *Activity 2: Atomic Math and Shorthand* may help introduce the concepts needed to complete this activity.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

• PS1. Structure and Properties of Matter.

Materials and Resources

- Evolution of a Radioactive Atom: Teacher Background Information.
- Vocabulary Materials.
- Computer and/or projector to display information.
- Decay Chain Examples (display or distribute to students) and Decay Chain Examples Teacher Answer Key.
- Decay Chain Worksheet (one per student, pair or group) and Decay Chain Teacher Answer Key teacher answer key.
- Periodic Table of Elements (to display or distribute to students).
- Student computers with Internet access to Radiation Basics: https://www.epa.gov/ radiation/radiation-basics

Time

45-60 minutes, not including optional activities or extensions.

Vocabulary

- Atom
- Alpha particles
- Beta particles
- Decay chain
- Gamma rays
- Half-life
- Ionizing radiation
- Radiation
- Radioactive atom
- Radioactive decay

Directions

- 1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.
- 2. Ask students what happens when things (e.g., plants, food and wood) decay. **Students should address how the items change in composition over time.** Prompt students to hypothesize whether things decay at the same rate and in the same way.
- 3. Ask students to hypothesize how radioactive atoms or materials decay. Radioactive decay occurs when an unstable (radioactive) atom gives off energy (in the form of ionizing radiation) as it attempts to become a stable atom and is no longer radioactive.
- 4. Display or provide students with a copy of the Decay Chain Examples.
- 5. Review the examples and work through the questions listed on the Decay Chain Examples Teacher Answer Key with students.
- 6. Distribute the Decay Chain Worksheet and the Periodic Table of Elements. Have students examine each decay chain, identify the elements (or isotopes) within each decay chain, and determine whether each transformation is due to the emission of an alpha or beta particle. The Decay Chain Teacher Answer Key provides questions and answers to review with students.
- 7. Have students share (orally or in writing):
 - What they have learned from the activity.
 - How we might use and benefit from radioactive elements that decay. We use radioactive elements for many different purposes. Beta-emitting elements with short half-lives are used in nuclear medicine, imaging and gauges. For example, cesium-137 is used in medical therapy to treat cancer and in moisture-density gauges, leveling gauges and thickness gauges. Alpha-emitting elements with longer half-lives are used for industrial purposes. For example, americium-241 is used in nuclear gauges, plutonium-238 is an alpha-emitting isotope that is used for generation of electric power in space probes.
- 8. Optional activities or extensions: Have students:
 - Diagram a decay chain for a particular radioactive element. The diagram can be simple (e.g., use elements with shorter chains or use a portion of longer decay chains) or complex, based on the time available. The diagram can be completed on paper or electronically.
 - Plot decay chains (e.g., using the radon chain on the Decay Chain Worksheet or others that students create) on a graph with the atomic numbers identified on one axis (x or y) and the atomic mass on the other (x or y).

Decay Chain Examples





Decay Chain Examples: Teacher Answer Key

Cesium (Cs)



Cesium–137 is an isotope of cesium that is produced when uranium and plutonium absorb neutrons and undergo fission (the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy; used to generate nuclear power).

Americium (Am)



Americium–241 is produced in the same process as Cesium-137; it is an isotope of americium that is used in ionizing smoke detectors and nuclear gauges.

The number of years listed in the example is the half-life for each element. Half-life is the amount of time it takes for approximately one-half of the radioactive atoms to decay. Radioactive elements decay at different rates (e.g., cesium has a half-life of 30.17 years and americium–241 has a half-life of 432.7 years).

- 1. What forms of radiation are released when cesium (Cs) converts to barium (Ba)? Beta particle and gamma rays.
- 2. What change occurs in the atomic properties of cesium (Cs) when it converts to barium (Ba)? Why?

The number of protons increases by one and cesium (55) becomes barium (56) because before a beta particle is released a neutron changes into a proton and an electron. The proton stays in the nucleus and the electron is ejected from the nucleus in the form of beta particles. The release of a beta particle decreases the number of neutrons by one and *increases the number of protons by one*.

- 3. What form of radiation is released when americium (Am) converts to neptunium (Np)? Alpha particle.
- 4. What change occurs in the atomic properties of americium (Am) when it converts to neptunium (Np)? Why?

An alpha particle is made up of two protons (+2) and two neutrons from the atom's nucleus. When the ratio of neutrons to protons in the nucleus is too low, certain atoms restore the balance by emitting alpha particles. This *reduces the number of protons by two*, changing americium (95) to neptunium (93).

U.S. EPA Education Activities: Evolution of a Radioactive Atom

Periodic Table of Elements

Group 2 3 12 7 9 14 15 16 18 4 5 6 8 10 11 13 17 Period IIA VB VIII VIII IIВ MA IIIB IVB MB MIB VIII IB IIIA IVA VA VIIA MIA IA 14 2A. 38 4B 58 6B 18 28 4A 5A 78 8 8 8 3A 6A 7A 8A Helium Hydrogen H He 1 Alkali metals Alkaline earth metals 1.008 4.003 Transition metals Lithium Neon Beryllium Carbon Nitrogen Flouride Element Name Boron Oxygen Post-transition metals 6 8 10 Atomic Number Metalloid B C 2 Li Be Symbol N F 0 Ne Lanthanides 6.94 9.012 Actinides 10.81 12.01 14.01 16.00 19.00 20.18 Atom ic Weight Nonmetals Auminium Sodium Magnesium Silicon hosphoru Sulfur Chlorine Argon Halogens 18 Mg Noble gases Si P S CI 3 Na A Ar 22.99 24.31 26.98 28.09 30.97 32.06 35.45 39.95 Potassium Calcium Gallium Scandium Titanium vanadium Chromium Manganes Iron Cobalt Nickel Zinc ermanium Arsenic Selenium Bromine Krypton Copper 19 20 26 27 29 30 32 33 34 36 22 24 31 Mn Ni K Ca Sc Ti V Cr Fe Co Cu Zn Ga Ge Se Br Kr As 4 39.10 40.08 44.96 47.88 50.94 52.00 54.94 55.85 58.93 58.69 63.55 65.39 69.72 72.64 74.92 78.96 79.90 83.79 Rhodium Silver 47 Rubidium Strontium Yttrium Zirconium Niobium Molybdenu chnetiur Ruthenium alladium Cadmiun Indium Tin 50 Antim ony Fellurium lodine Xenon 39 Y 54 40 49 52 Rb Sr Mo Pd Cd Sb Xe Zr Nb Te Rh Sn Te Ru Ag In 1 5 88.91 91.22 102.9 106.4 112.4 126.9 85.47 87.62 92.91 95.94 (98) 101.1 107.9 114.8 118.7 121.8 127.6 131.3 Caesium Hamium Tantalum Iridium Platinum Gold Mercury Thallium olonium Astatine Radon Barium Tungster Rhenium Lead Bismuth 57-70 Pb 55 56 75 76 77 78 79 80 84 85 86 Hf Cs Hg TI Ba * Ta Re Pt. Bi Po At W Og Ir Rn 6 Au 132.9 137.3 178.5 180.9 186.21 192.2 195.1 197.0 204.4 207.2 183.9 190.2 200.5 209.0 (209)(222) Rutherfordiu Dubnium Seaborgiu Bohnum Hassium Meitnerium Darmsta dtiur Roentgenium Ununquadiur Ununhexium Ununseptium Ununoctium Francium Radium Copernium Ununtrium Ununpentiun 89-102 87 88 110 111 112 113 114 115 117 118 104 Rf Db ** Bh Mt Ds Fr Sg HS Uut Uuq Uup Uuh Uus 7 Ra Rg Cn Uuo (265) (268) (271) (280) (285) (284) (289) (288) (226) (270) (277)(276) (281) (293) (294) (294) Lanthanum Thulium Ytterbium Lutetium Cerium raseodym la leodymiu Promethiu Samarium Eurpoium Gadolinium Terbium Dysprosium Holmium Erbium 58 59 60 61 65 66 57 62 63 64 67 68 69 70 71 * Lanthanoids Gd La Ce Pr Nd Sm Eu Tb Dy Ho Er Yb Pm Tm LU 138.9 140.1 140.9 144.2 (145) 150.4 152.0 157.2 158.9 162.5 164.9 167.3 168.9 173.0 175.0 Actinium lutonium lendelevi Bobelium awrenciu Thorium roactiniu Uranium leptuniur Americium Curium Berkeliun alifornium insteiniu Femium 89 94 95 96 100 101 102 103 90 91 92 93 98 99 ** Actinoids Cf Th U Bk. Md Ac Pa Np Pu Es Fm No Lr Cm Am 238 (242) (243) (247) (247) (251) (252) (257) (258) (259) (262)

Decay Chain Worksheet

Examine each decay chain and identify the element. Then indicate whether each transformation is due to the emission of an alpha or beta particle by writing in the corresponding symbol. Sometimes gamma rays are released but because the release of gamma rays does not affect atomic mass or atomic number the exercise is focused on alpha and beta emissions.



Decay Chain: Teacher Answer Key

Examine each decay chain and identify the element. Then indicate whether each transformation is due to the emission of an alpha or beta particle by writing in the corresponding symbol. Sometimes gamma rays are released but because the release of gamma rays does not affect atomic mass or atomic number the exercise is focused on alpha and beta emissions.

