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:* http://www2.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.

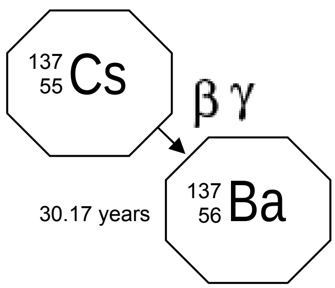
6. Distribute the *Decay Chain Worksheet* and the *Periodic Table of Elements*. Have students examine each decay chain, identify the elements (or isotopes) within each decay chain, and determine whether each transformation is due to the emission of an alpha or beta particle. The *Decay Chain Teacher 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.**

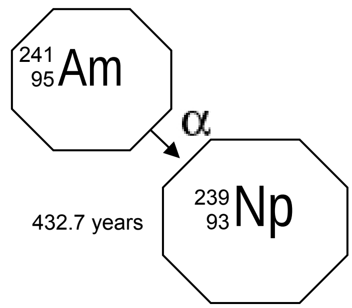
8. Optional activities or extensions: Have students:
   - Diagram a decay chain for a particular radioactive element. The diagram can be simple (e.g., use elements with shorter chains or use a portion of longer decay chains) or complex, based on the time available. The diagram can be completed on paper 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

Cesium (Cs)



Americium (Am)

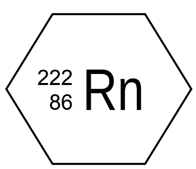


Key

Alpha particle: α

Beta particle: β

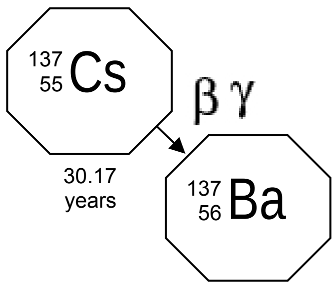
Gamma ray: γ



In the example, Rn is the atomic symbol for the element Radon. The number 222 indicates the atomic mass of the element (or isotope). The number 86 respresents the element's atomic number.

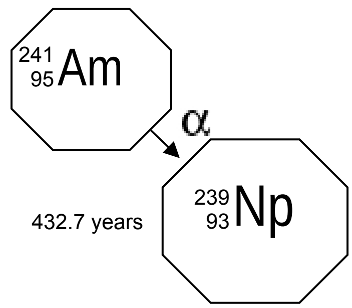
Decay Chain Examples <u>Teacher Answer Key</u>

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).

Periodic Table of Elements

Element Name Atomic Number Symbol Atomic Weight

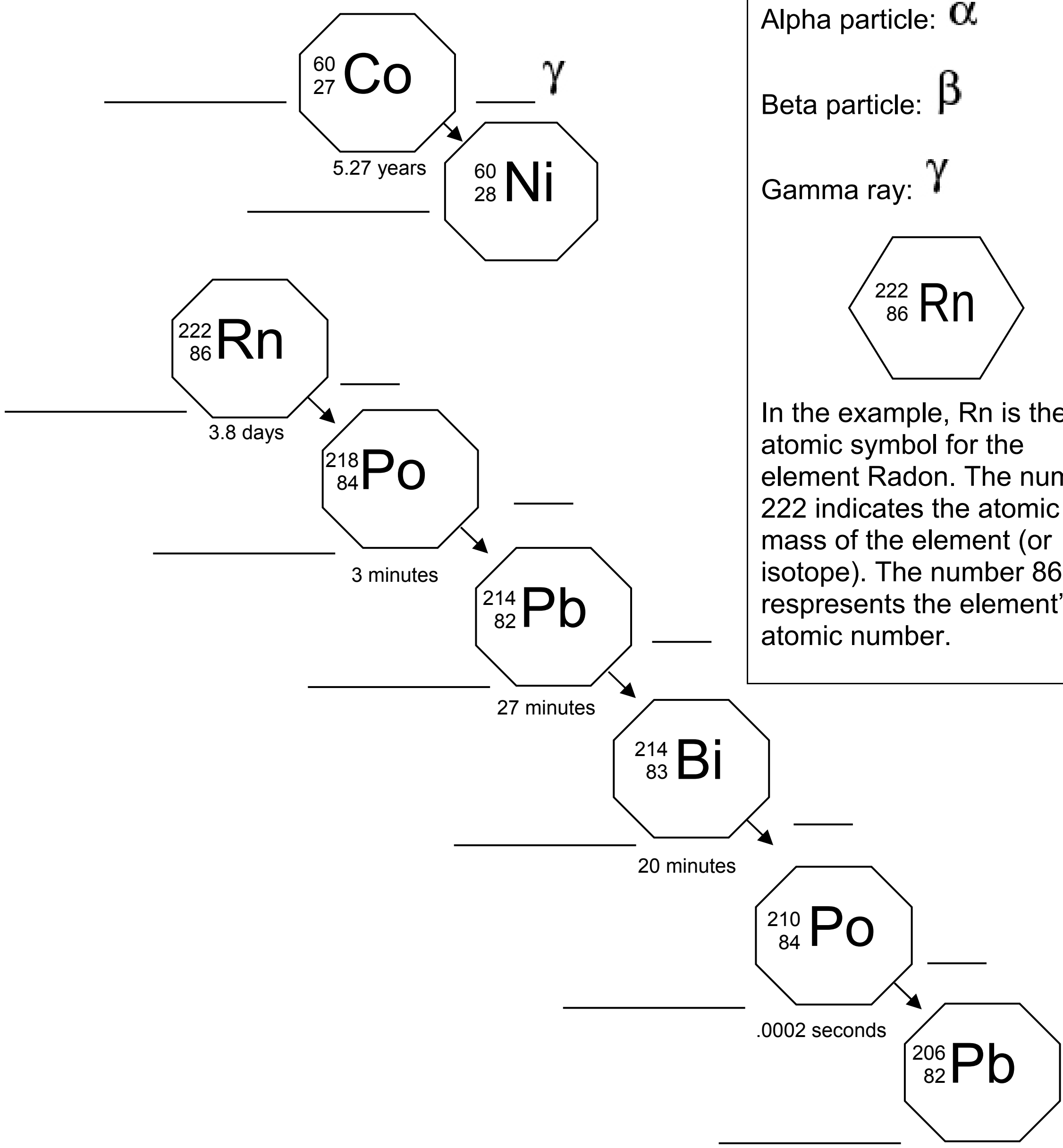
- Alkali metals
- Alkaline earth metals
- Transition metals
- Post-transition metals
- Metalloid
- Lanthanides
- Actinides
- Nonmetals
- Halogens
- Noble gases

Period \ Group	1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1	Hydrogen 1 H 1.008																	Helium 2 He 4.003
2	Lithium 3 Li 6.94	Beryllium 4 Be 9.012											Boron 5 B 10.81	Carbon 6 C 12.01	Nitrogen 7 N 14.01	Oxygen 8 O 16.00	Flouride 9 F 19.00	Neon 10 Ne 20.18
3	Sodium 11 Na 22.99	Magnesium 12 Mg 24.31											Aluminium 13 Al 26.98	Silicon 14 Si 28.09	Phosphorus 15 P 30.97	Sulfur 16 S 32.06	Chlorine 17 Cl 35.45	Argon 18 Ar 39.95
4	Potassium 19 K 39.10	Calcium 20 Ca 40.08	Scandium 21 Sc 44.96	Titanium 22 Ti 47.88	Vanadium 23 V 50.94	Chromium 24 Cr 52.00	Manganese 25 Mn 54.94	Iron 26 Fe 55.85	Cobalt 27 Co 58.93	Nickel 28 Ni 58.69	Copper 29 Cu 63.55	Zinc 30 Zn 65.39	Gallium 31 Ga 69.72	Germanium 32 Ge 72.64	Arsenic 33 As 74.92	Selenium 34 Se 78.96	Bromine 35 Br 79.90	Krypton 36 Kr 83.79
5	Rubidium 37 Rb 85.47	Strontium 38 Sr 87.62	Yttrium 39 Y 88.91	Zirconium 40 Zr 91.22	Niobium 41 Nb 92.91	Molybdenum 42 Mo 95.94	Technetium 43 Tc (98)	Ruthenium 44 Ru 101.1	Rhodium 45 Rh 102.9	Palladium 46 Pd 106.4	Silver 47 Ag 107.9	Cadmium 48 Cd 112.4	Indium 49 In 114.8	Tin 50 Sn 118.7	Antimony 51 Sb 121.8	Tellurium 52 Te 127.6	Iodine 53 I 126.9	Xenon 54 Xe 131.3
6	Caesium 55 Cs 132.9	Barium 56 Ba 137.3	57-70 *	Hafnium 72 Hf 178.5	Tantalum 73 Ta 180.9	Tungsten 74 W 183.9	Rhenium 75 Re 186.21	Osmium 76 Os 190.2	Iridium 77 Ir 192.2	Platinum 78 Pt 195.1	Gold 79 Au 197.0	Mercury 80 Hg 200.5	Thallium 81 Tl 204.4	Lead 82 Pb 207.2	Bismuth 83 Bi 209.0	Polonium 84 Po (209)	Astatine 85 At (210)	Radon 86 Rn (222)
7	Francium 87 Fr (223)	Radium 88 Ra (226)	89-102 **	Rutherfordium 104 Rf (265)	Dubnium 105 Db (268)	Seaborgium 106 Sg (271)	Bohrium 107 Bh (270)	Hassium 108 Hs (277)	Meitnerium 109 Mt (276)	Darmstadtium 110 Ds (281)	Roentgenium 111 Rg (280)	Copernium 112 Cn (285)	Ununtrium 113 Uut (284)	Ununquadium 114 Uuq (289)	Ununpentium 115 Uup (288)	Ununhexium 116 Uuh (293)	Ununseptium 117 Uus (294)	Ununoctium 118 Uuo (294)

* Lanthanoids	Lanthanum 57 La 138.9	Cerium 58 Ce 140.1	Praseodymium 59 Pr 140.9	Neodymium 60 Nd 144.2	Promethium 61 Pm (145)	Samarium 62 Sm 150.4	Eurpoium 63 Eu 152.0	Gadolinium 64 Gd 157.2	Terbium 65 Tb 158.9	Dysprosium 66 Dy 162.5	Holmium 67 Ho 164.9	Erbium 68 Er 167.3	Thulium 69 Tm 168.9	Ytterbium 70 Yb 173.0	Lutetium 71 Lu 175.0
** Actinoids	Actinium 89 Ac (227)	Thorium 90 Th 232	Proactinium 91 Pa 231	Uranium 92 U 238	Neptunium 93 Np (237)	Plutonium 94 Pu (242)	Americium 95 Am (243)	Curium 96 Cm (247)	Berkelium 97 Bk (247)	Californium 98 Cf (251)	Einsteinium 99 Es (252)	Fermium 100 Fm (257)	Mendelevium 101 Md (258)	Bobelium 102 No (259)	Lawrencium 103 Lr (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.



Key

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Beta particle: β

Gamma ray: γ

In the example, Rn is the atomic symbol for the element Radon. The number 222 indicates the atomic mass of the element (or isotope). The number 86 respresents the element's atomic number.

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.

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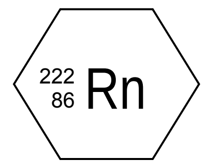

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