Edgenuity

Warm-Up | Radioactivity

Lesson Question

What is radioactivity?

Lesson Goals

Describe radioactivity.

- **Distinguish** between alpha, beta, and gamma decay.
- **Explain** the rate of decay of an isotope using the half-life concept.
- **Identify** technological applications of radioactive decay.
- **Determine** possible problems associated with radioactive decay.

Words to Know

Write the letter of the definition next to the matching word as you work through the lesson. You may use the glossary to help you.

C	strong nuclear force	A. the spontaneous discharge of energy from an unstable nucleus
A	radioactivity	B. the time required for half of a sample of a radioisotope to decay
E	weak nuclear force	C. the force that binds neutrons and protons together in the nuclei of atoms
B	half-life	D. an atom with an unstable nucleus that will eventually go through radioactive decay
D	radioisotope	E. the force that is responsible for the type of radioactive decay known as beta decay

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Words to Know

H ionizing radiation

F radioactive decay

G stochastic

F. the process in which the nucleus of an unstable isotope spontaneously changes, releasing particles and energy

G. involving chance or randomness; the likelihood that something will happen

H. radiation with sufficient energy to cause potential DNA damage due to ionized atoms and broken molecular bonds

The Nucleus

- The central part of the atom, the nucleus, contains protons and neutrons.
- A nucleus can be described by its atomic number and mass number.
  - The atomic number stays the same.
  - The mass number may change.

Isotopes

- An isotope is identified by its mass number.
- It has the same number of protons but a different number of neutrons than other atoms of the same element.

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Radioisotopes

- The **strong nuclear force** binds protons and neutrons together in the nucleus.
- Nuclear stability depends on the neutron-to-proton ratio and the size of the nucleus.
  - Too few neutrons relative to protons can lead to instability.
  - As the size of the nucleus increases, more neutrons are needed to maintain the attractive force.
- An unstable isotope is called a **radioisotope**.

Radioactive Decay

- **Radioactive decay** is the process in which the nucleus of an unstable isotope spontaneously changes, releasing particles and energy.
  - The spontaneous discharge of energy is called radioactivity.
- An unstable isotope continues the decay process until it reaches a stable form.
  - Carbon-14 → nitrogen-14

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Types of Radioactive Decay

Particle	Composition	Charge	Effect
Alpha (α)	2 protons, 2 neutrons	+2	Mass loss, new element
Beta (β)	Electron or positron	−1 +1	Same mass number, new element
Gamma (γ)	Photon	0	Energy loss

Weak Nuclear Force

- There are two types of beta decay:
  - An electron is emitted from a neutron during beta minus decay, creating an extra proton.
    - A new element is created with one higher atomic number on the periodic table.
  - A positron is emitted from a proton during beta plus decay, creating an extra neutron.
    - A new element is created with one lower atomic number on the periodic table.
- The **weak nuclear force** is responsible for both types of beta decay.

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Rates of Radioactive Decay

- Different radioisotopes decay at different rates.
- **Half-life** is the time required for half of a sample of a radioisotope to decay.
- The half-life for any particular isotope is constant.

Radioisotope	Half-Life
rubidium-91	58.4 seconds
iodine-131	8 days
cobalt-60	5 years
carbon-14	5730 years
cesium-135	2.3×10^6 years
uranium-238	4.5×10^9 years

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Radioactive Decay and Half-Life

- Radioisotopes decay until they reach a stable form.
- For each half-life that occurs, half of the atoms will change to a stable isotope and the other half will remain unchanged.

Number of Half-Lives	Percentage of Radioisotope	Percentage of Stable Isotope
0	100%	0%
1	50%	50%
2	25%	75%
3	12.5%	87.5%
4	6.25%	93.75%

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Radioactive Decay and Half-Life

- The half-life of an isotope can be used to calculate:
  - the time it would take for a given percentage of a sample to decay.
  - the percentage of a sample remaining after a specific number of years have passed.

The half-life of strontium-90 is 28.8 years. How long will it take for $\frac{3}{4}$ of a sample of strontium-90 to decay?

Sample-%	Fraction	Half-Life
100	1	0
50	$\frac{1}{2}$	28.8 Y
25	$\frac{1}{4}$	57.6 Y
12.5	$\frac{1}{8}$	86.4 Y

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Radioactive Decay and Half-Life

Potassium-40 has a half-life of 1.3 billion years. What percentage of a sample of potassium-40 would remain after 6.5 billion years?

Sample-%	Fraction	Half-Life
100	1	0
50	$\frac{1}{2}$	1.3
25	$\frac{1}{4}$	2.6
12.5	$\frac{1}{8}$	3.9
6.25	$\frac{1}{16}$	5.2
3.125	$\frac{1}{32}$	6.5

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Medical Uses

- Doctors use radioisotopes to detect medical problems.
  - A radioisotope is injected into the body.
  - It moves to the targeted part of the body.
  - It goes through radioactive decay.
  - The radiation is detected with special equipment.

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Medical Uses

- Radioisotopes are used in radiation therapy.
  - Radiation from isotopes kills unwanted cells.
  - For other types of cancer, high-energy gamma rays are directed at the tumor from outside the body. This radiation kills the cancer cells.

Agricultural Uses

- Scientists use radioisotopes to study the biological and chemical processes in plants.
  - The radioisotope is chemically identical to the nonradioisotope normally used by the plant.
  - The radioisotope gives off radiation that is easily detected by a device such as a Geiger counter.

Geological and Archaeological Uses

- Geologists use radioisotopes to determine the age of rocks and fossils.
- Archaeologists use radioisotopes to determine the age of ancient artifacts.

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Radiation and Health

- Radioactive materials produce ionizing radiation, which can damage living cells.
- Examples of ionizing radiation:
  - Ultraviolet radiation in sunlight
  - X-rays used in medical imaging
  - Gamma rays produced by radioactive materials

The effects of radiation on health depend on the amount and duration of exposure.

Stochastic Effects

- Associated with long-term, low-level exposure
- Include cancer and other DNA mutations

Non-Stochastic Effects

- Associated with short-term, high-level exposure
- Include burns and radiation sickness

- Several precautions are taken to protect individuals from radiation exposure.
  - Proper handling
  - Lead shielding
  - Limited exposure

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Nuclear Power

- The main nuclear fuels are uranium and plutonium; both are radioactive.
- During radioactive decay, nuclear fuels release heat, which is used to boil water.
- The expanding steam spins turbines, driving generators to produce electricity.
- If an accident occurs, large amounts of radioactive materials are released into the environment.
- Nuclear waste remains hazardous for thousands of years.

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Nuclear Disasters

- The Chernobyl disaster of 1986 in the Ukraine is the worst nuclear power plant accident in history.
- The Fukushima Daiichi disaster of 2011 in Japan is the largest nuclear incident since the Chernobyl disaster.

- The United States had its worst commercial nuclear accident at the Three Mile Island plant.
- This plant's number two core was damaged and radiation was released into the air, causing the environment to suffer a tremendous amount of damage.
- It took 14 years and $1 billion to clean up the mess.

Summary | Radioactivity

Lesson Question

What is radioactivity?

Answer

(Sample answer) Radioactive decay is the process in which the nucleus of an unstable isotope spontaneously changes, releasing particles and energy. The spontaneous discharge of energy is called radioactivity.

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Review: Key Concepts

- The strong nuclear force and weak nuclear force both act in the atomic [nucleus].
- An unstable isotope is called a radioisotope.
- Radioactive decay is the process in which the nucleus of an unstable isotope spontaneously changes, releasing particles and [energy].
    - The spontaneous discharge of energy is called radioactivity.
    - There are three main types of radioactive decay: alpha, beta, and gamma.
- Half-life is the time required for half of a sample of a radioisotope to decay.
- Radioactive decay has many technological applications, including medicine, [agriculture], geology, and archaeology.
- Radioactive materials can be [dangerous] and must be handled properly.

Summary | Radioactivity

Use this space to write any questions or thoughts about this lesson.