

# #10380 RADIOACTIVITY

BENCHMARK MEDIA, 2001

Grade Level: 10-13+

15 Minutes



## CAPTIONED MEDIA PROGRAM RELATED RESOURCES

[#3350 CHEMISTRY: THE BASICS](#)

**RADIOACTIVITY**

*15 minutes, Video*

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**FOR USE IN: Chemistry**

**LEVEL: Grades 9-12**

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**EDUCATIONAL OBJECTIVES:**

To help the student understand these 3 key concepts about radioactivity, each runs 5 minutes, and is separately titled:

- ⇒ 1. Detection and Origin
- ⇒ 2. Types and Properties
- ⇒ 3. Measuring and Using Half-Life

Note: to play only Concepts #2 or #3, simply fast forward until you see its title.

**BACKGROUND TO VIDEO**

Nuclear chemistry is the study of those elements that are radioactive. Radiation is the spontaneous emission of particles or rays from the nucleus of a radioactive element. Not all nuclei decay spontaneously and so some, therefore, are stable. Others, however, are unstable. There are common types of radioactive emissions such as alpha and beta particles and gamma rays. Each of these has a particular mass and charge and their emission determines the remaining mass of the element produced as well as the number of protons that will be in the nucleus of the element. A new element will be produced if the number of protons changes or the same element will be produced if the number of protons in the nucleus does not change.

Though the energy emitted from different types of radioactive particles can be harmful, there are many practical uses for radioactive elements because the rate at which they decay is known. Because radiation is emitted continuously, they can be used for such applications as radioactive dating, treatment of cancerous tumors, and in research as radioactive tracers. The progress of a reaction can be followed and information can be determined about intermediate products that could assist in the development of a new drug to block a harmful intermediate product.

A Geiger-Muller counter is utilized to detect the presence of radioactivity. It is really a gas ionization counter. Radiation enters through the window of the counter. The presence of radiation ionizes one or more gaseous atoms inside the counter. The electrons and positive ions that are produced result in a pulse of electric current that travels through wires, is amplified, and displayed on a meter or other readout. The Geiger counter can detect alpha and beta radiation.

In 1896 Henri Becquerel wrapped a photographic plate in black paper. A nearby enclosed sample of potassium uranyl sulfate, though, caused exposure of the photographic plate and the plate darkened. The plate would only have darkened with exposure to light and since there was no light, it had to be the uranium compound that caused it to darken.

C. T. R. Wilson devised the first cloud chamber in 1911. Air molecules are ionized inside the chamber by particles emitted from a radioactive substance. When the chamber is cooled, droplets of liquid condense on the ions and the path of the particles can be followed.

## **CONTENT OF THE VIDEO**

This program explains that radioactivity is all around us and is emitted from different sources. Radioactivity is invisible and two experiments demonstrate its effects: one is a replication of Henri Becquerel's first discovery of radioactivity on photographic film; the other shows the path of radioactivity in a cloud chamber. One major use of radioactivity is in nuclear medicine, and you will see the use of a 'tracer' in the investigation of a patient's kidney functions. The half-life of radioactive barium is calculated and students are asked to calculate the half-life of the tracer. The program is in three parts: 1 Detection and origin 2 Types and properties 3 Uses of radioactivity and measurement of half life. Each part is described in more detail below.

### **1 Detection and Origin**

Radioactivity is invisible, but a Geiger - Muller tube connected to a counter can be used to detect different levels. It is really a gas ionization counter. Radiation enters through the window of the counter. The presence of radiation ionizes one or more gaseous atoms inside the counter. The electrons and positive ions that are produced result in a pulse of electric current that travels through wires, is amplified, and displayed on a meter or other readout. The Geiger counter can detect alpha and beta radiation.

Wherever you are, there is some background radioactivity given off by materials, such as rocks that contain uranium, and luminous paint that contains radium. Cosmic rays from outer space also add to background radioactivity. To understand radioactivity, we need to look at atomic structure. The nucleus of an atomic atom is unstable and can break up at any time, releasing radioactivity. Radioactivity was first discovered by the French scientist, Henri Becquerel, just over 100 years ago. He found that objects left on top of a light-tight photographic plate affected it. Leaving radioactive objects on a light-sealed box, with photographic film inside can mimic this experiment. When the film is developed, the radioactivity given off is visible.

Another way to see the effects of radioactivity is in a cloud chamber. The cloud chamber contains air saturated with alcohol vapor and a radioactive alpha source. As the radiation shoots through the alcohol, it leaves behind a trail of alcohol clouds, because nuclear radiation ionizes air. When the alpha radiation collides with atoms in the air, it dislodges electrons, leaving positive ions. Alcohol condenses on the ions, leaving trails of alcohol droplets, which trace the path of the radiation.

### **2 Types and Properties**

There are three different types of radiation - alpha, beta and gamma radiation.

Beta radiation, emitting 600 counts/second, is slightly blocked by paper and completely blocked by a thin aluminium sheet. Beta radiation is a stream of high-energy negatively charged electrons and a negative magnetic field will deflect this stream.

Alpha radiation emitting 500 counts/second is absorbed by paper. Alpha particles are lost from the nucleus of an atom and consist of two neutrons and two protons. They are positively charged. **Video Question:** How would you expect Alpha particles to be affected by a positive or a negative magnetic field? **Answer:** Since Alpha particles are positively charged, they are repelled by a positive field, and attracted to a negative field. This is the opposite of Beta negatively charged particles.

Gamma radiation are emissions of photons in the high frequency end of the electromagnetic spectrum and as such are highly penetrating. A source emits 500 counts/second of gamma radiation, which is not absorbed by either paper or aluminum. Several sheets of lead are needed to block it. The photons in Gamma radiation have no charge and so are not affected by magnetic fields.

### 3 Uses of radioactivity and Measurement of Half life

Hospitals use radiation in a number of ways in their nuclear medicine departments. Radioactive tracers are injected into the body and accumulate in a target organ - in this case, the kidneys. Gamma rays given off by a tracer pass out of the kidneys and the body to create an image on a gamma camera. Radioactive atoms decay to form new atoms. The sample becomes less radioactive. The count given off by barium 137M is recorded over time. This is plotted and its half-life, that is the time it takes for the counts/second to fall by one half, can be calculated. The counts from the tracer in the patient's body were:

Time	09.00	11.00	13.00
Counts/second	112 million	88 million	67 million.

**Video Question:** Technetium-99m has a half life of 6 hours. How much would the activity of Tc-99m drop after 24 hours? **Answer:** If the original count of Tc-99m was 80 at time zero, the count would be 5 twenty-four hours later. The following represents the change in count during 24 hours

Time	0	6 hrs.	12 hrs.	18 hrs.	24 hrs.
Million counts/sec	80	40	20	10	5

### AFTER SHOWING THE VIDEO:

The following are questions to stimulate classroom discussion:

**Q.** What do you think are the common characteristic components of stable and unstable atoms?

**A.** Elements with an atomic number greater than 83, such as radium, are all radioactive. More specifically, when the neutron-to-proton ratios of nuclei lie outside a region of stability, then the elements are radioactive. The most stable elements of low atomic number have equal numbers of protons and neutrons. When the atomic number is greater than 20, stable elements have more neutrons than protons. Outside the region of stability the elements spontaneously emit one or more particles or electromagnetic rays or both.

**Q.** Compare the penetrating power, mass, and charge of Beta, Alpha, and Gamma emissions.

**A.** When the different particles or electromagnetic radiation are emitted from the nucleus, they possess a certain amount of kinetic energy or energy of motion. The kinetic energy is proportional to the penetrating abilities of the particles or rays. Alpha particles, that move a lot slower than beta particles, have only 1/100th of the penetrating power of beta particles. Alpha particles cannot damage or penetrate skin, whereas beta particles can burn skin severely. Gamma rays, because of their penetrating power, can damage both skin and internal organs.

The following information provides a representation of alpha, beta, and gamma rays

Type	Symbols	Charge
alpha	$\alpha$ , ${}^4_2\alpha$ , ${}^4_2\text{He}$	2+
beta	$\beta^-$ , ${}^0_{-1}\beta$ , ${}^0_{-1}\text{e}$	1-
gamma	${}^0_0\gamma$ ray	0

The numerator in the symbol represents the mass of the particle or ray and the denominator represents the charge. For an alpha particle, the mass is equal to 4 and the charge is equal to 2+.

**Q.** How are Gamma rays different from both Alpha, and Beta, and why is its penetrating power so great?  
**A.** Gamma radiation is not like alpha and beta particles because it is a form of electromagnetic radiation. The electromagnetic spectrum represents the various types of electromagnetic radiation. Visible light, with which we are most familiar, ranges in wavelength from 4000 to 7000 Å (1 Å =  $1 \times 10^{-10}$  m). The frequency of visible light is around  $10^{15}$ /s. Gamma radiation has a wavelength around  $10^{-3}$  Å and a frequency around  $10^{21}$ /s. Frequency is proportional to energy so gamma radiation would be  $10^6$  times more energetic than visible light. All electromagnetic radiation can be described as composed of particles or photons. The energy, therefore, of a photon of light will be determined by which part of the electromagnetic spectrum is involved.

**Q.** Develop equations for the half-life of a radioactive substance; of Technetium-99m; of Cobalt-60?

**A.** Technetium is a radioisotope that does not occur naturally on earth. When Molybdenum-99 decays by beta emission, Technetium-99m is formed, as shown by the equation:



Technetium-99m slowly decays with a half-life of 6.0 hours through the emission of gamma radiation shown by the equation:

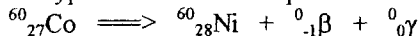


The decay rate for a radioactive substance is usually expressed in terms of the half-life,  $t_{1/2}$ , of the substance.

The equation is:  $t_{1/2} = \frac{0.693}{k}$

Half-life pertains to the amount of time it takes for one half of the original amount of substance to react.

The rate constant,  $k$ , varies based on the radioactive substance. Using a graph of mass of sample vs. time, the time it will take for a substance of a particular mass to decay can be determined. Cobalt-60 is utilized to treat certain types of cancer. The equation of its decay to a simpler atom is:



#### EXPLORING AND INVESTIGATING

1. What role did Marie Curie play in the story of radioactivity?
2. Is all radiation detrimental to your health? What makes radiation dangerous?
3. What happened to watch makers who utilized radium to make the hands of watches glow?
4. What is Fiestaware? What problems are associated with older Fiestaware?
5. Research whether there is a better metal than lead to stop the penetration of gamma rays during an x-ray. What are its advantages and disadvantages?
6. What are some of the practical uses of alpha, beta, and gamma radiation?
7. When some form of radiation is utilized to determine or treat a medical problem, are there harmful effects on other parts of the body? Why or why not?
8. What is a barium swallow test and what is its use?
9. Research the presence of radon gas in the home. What area of the United States is strongly effected by its presence and what has been done to alleviate the problem?