GAMMA RADIATION FAQ & GLOSSARY

WHAT IS GAMMA RADIATION?

Gamma radiation is a form of electromagnetic radiation caused by gamma rays. Gamma rays are the result of nuclear decay, which occurs when the nucleus inside an **unstable atom** loses energy in an attempt to stabilize.

unstable atom: an atom with too much internal energy.

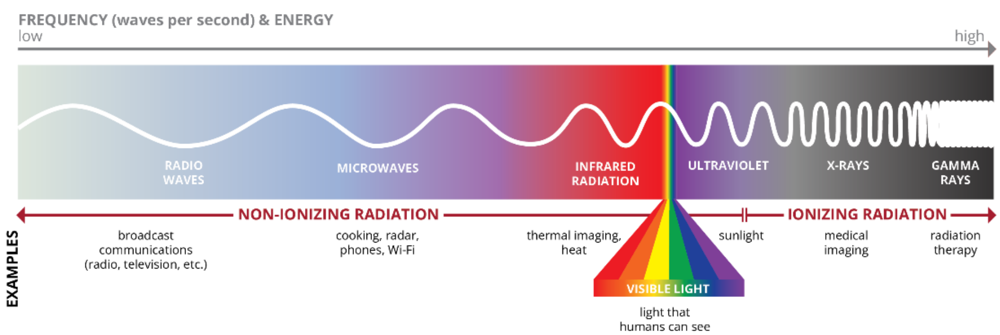
ELECTROMAGNETIC SPECTRUM

On the **electromagnetic spectrum**, gamma radiation is a form of **ionizing radiation**, which means the rays can remove or add electrons from atoms. Other forms include alpha, beta, and x-ray radiation. Microwave, infrared, visible light, and ultraviolet are forms of **non-ionizing radiation**. Gamma rays also have very high frequencies and are very high energy, compared to other forms of radiation on the spectrum.

electromagnetic spectrum: full range of electromagnetic radiation that classifies forms of radiation based on several properties.

ionizing radiation: the result of unstable atoms attempting to stabilize. Exposure can cause serious health effects because this radiation can greatly impact living tissue at a cellular level.

non-ionizing radiation: does not have enough energy to add or remove electrons. Exposure to some forms, like UV light from the sun, can cause health effects such as burns or skin cancer. Other than sunlight, the general public is typically not at a huge risk of health effects from non-ionizing radiation, but some workplaces may pose a higher risk.



EXPOSURE TO GAMMA RADIATION

Unlike other forms of ionizing radiation, gamma rays penetrate deep into our cells and can only be stopped by very thick layers of concrete or lead.

Exposure to gamma radiation can cause nausea, skin burns, and other radiation poisoning symptoms such as fatigue, fever, hair loss, and dehydration. Gamma rays can alter our DNA and increase our risk of cancer.

WHAT ARE SOME SOURCES & USES OF RADIATION?

NATURAL BACKGROUND RADIATION

Various forms of ionizing radiation (alpha, beta, gamma, and x-ray) exist in our natural environment:

- Cosmic events, like lightning, solar flares, and black holes, can cause some radioactive particles to pass through our atmosphere to earth. People at higher altitudes may experience higher exposure to these particles.

- Soil and rocks, due to the decomposition of natural radioactive material. This material can end up in consumer products like building materials, tobacco, and drinking water. Some buildings and homes are at higher risks of **radon** build-ups, especially in basements.

MEDICAL RADIATION

Radiation has been harnessed for various medical applications, including diagnosing, monitoring and treating many conditions such as cancer. Specific applications include:

- **Medical imaging**, with x-rays, CT scans, and PET scans.
- Radiation therapy treatments to destroy **mutated cells**, either through beamed, targeted destruction or the ingestion of **radiopharmaceuticals**.

NON-MEDICAL RADIATION

- Nuclear weapons:
  - Atomic bombs use **nuclear fission** of uranium or plutonium, which releases enormous amounts of heat and gamma rays, causing environmental destruction, death, and health effects like cancer.
  - **Radiological Dispersal Devices (RDD)** are explosives that contain radioactive material. This weapon is typically associated with terrorism, because the threat of detonation can cause mass panic in a population. RDDs have never been detonated outside of testing environments.
- Nuclear power plants, which generate electricity. Nuclear energy is considered a clean energy source due to the lack of emissions (unlike the burning of coal or fossil fuels).
- Some household items, such as smoke detectors, which may use a small amount of a low-level radioactive material sealed inside the detector to help detect smoke, or old watches with radium luminescent paint on the hands and dials.

WORKPLACES

Exposure to radiation may be higher for some occupations due to the location or nature of the work being performed, such as:

- Emergency responders and environmental clean-up workers after the sudden release of radioactive material.
- Miners, especially of radioactive material such as uranium.
- Healthcare workers treating radiation injuries or administering imaging tests and radiation therapies.
- Nuclear power plant employees.

radon: colorless and odorless gas that comes from the breakdown of radioactive elements in the ground. Radon detectors may be an important tool for some households.

medical imaging: in x-rays and CT scans, medical professionals use x-ray radiation to take a "picture" of the body. X-rays can help doctors diagnose factures, swelling, or other issues. CT scans use slightly more radiation to help doctors locate tumors, infections, or blood clots and guide surgeons through various procedures. Radiation does not linger in the body after these scans are completed.

In PET scans, patients are injected with a safe amount of a radioactive substance to show doctors a live view of the body to determine any changes to the function of tissues and organs. Doctors observe how the body reacts to the radioactive substance – diseased cells will absorb much more of the radioactive substance than healthy cells. PET scans can be used to diagnose various cancers, brain disorders, and heart diseases much earlier than other forms of imaging. Radiation may linger in the body for a short time after a PET scan.

mutated cells: occur when DNA within a cell has changed during cell division and replication.

radiopharmaceuticals: drugs that bind to and kill cancer cells. Patients undergoing this treatment usually remain in the hospital until their radiation levels decrease after each treatment session.

nuclear fission: forcing a neutron (uncharged particle) to strike the nucleus of an atom, causing the nucleus to split in half.

Radiological Dispersal Devices (RDD): also known as dirty bombs.

All these workers are closely monitored to ensure their exposure does not exceed acceptable levels. These workplaces can also implement a number of engineering and administrative controls to protect workers, in addition to providing Personal Protective Equipment (PPE).

HOW IS GAMMA RADIATION MEASURED?

MEASUREMENT STRATEGIES

Ionizing radiation (alpha, beta, gamma, and x-ray) – is typically measured in three ways:

- **Radioactivity**, to indicate the amount of radiation that has been released by a material in a given time period. Used when measuring soil, water or air samples.
- **Absorbed dose**, to indicate the amount of radioactive energy that has been absorbed into a given mass. Used when measuring exposure from medical imaging tests, like CT scans.
- **Effective dose**, to indicate the potential for long-term health effects from exposure in a population over a given time.

radioactivity: measured in becquerels (international unit) or curies (USA unit).

absorbed dose: measured in grays (international unit) or rads (USA unit).

effective dose: similar to equivalent dose, which considers radiation type but not organ type.

Effective dose is typically what is monitored by gamma radiation detectors. It is also the measurement strategy that helps set regulatory limits and guidelines for exposure. Effective dose is measured in **sieverts** (Sv) or **rem**.

Sieverts: 1 Sv = 100 rem. International unit.

Rem: 1 rem = 0.01 Sv. USA unit. Stands for Roentgen equivalent man. Based on the legacy unit of roentgens.

To calculate the effective dose, the absorbed dose is adjusted based on the specific type of radiation (alpha, beta or gamma), the organs that might be affected, and the means of exposure (external contact vs. inhalation). This gives an approximation of anticipated health effects but does not provide a physical quantity in an individual.

Exposure Comparisons

Effective Dose	Dental x-ray	Chest x-ray	Sea level	Higher elevation	Uranium mine or nuclear power plant in Canada	Radon in average US home	Chest CT scan	Whole body CT scan	Astronaut on International Space Station
One-time	0.005 mSv	0.1 mSv					7 mSv	10 mSv	
Annual			0.3 mSv	0.8 mSv	1 mSv	2.28 mSv			150 mSv

Sources: Canadian Nuclear Safety Commission | United States Environmental Protection Agency

EXPOSURE LIMITS

Exposure limits are regulated in many countries for occupational workers – people who work with and around radioactive materials, including exposure to artificial radiation (nuclear reactors, healthcare, manufacturing) and elevated exposure to natural radiation (flight crews, mining, construction).

Most countries measure the effective dose in millisieverts (mSv) per year. The United States also includes measurements in millirems (mrem) per year.

Regulated Effective Dose in Canada, USA and Europe

	Canada*	USA*	Europe**
Regulation	Radiation Protection Regulations	Standards for Protecting Against Radiation	Council Directive 2013/59/Euratom (European Atomic Energy Community)
Whole body	50 mSv/year	50 mSv/year 5000 mrem/year	20 mSv/year
Hands, feet and skin	500 mSv/year	500 mSv/year 50,000 mrem/year	500 mSv/year
Eye lens	50 mSv/year	150 mSv/year 15,000 mrem/year	20 mSv/year

**Regulations also define non-occupational limits (average person's annual dose of natural background radiation) that are lower than occupational limits (~1 mSv).*

***Regulations also define occupational limits for workers under 18 and special regulations for uterus and fetus exposure.*

HOW IS GAMMA RADIATION DETECTED?

The current industry standard in radiation detection is the **scintillator** crystal detector.

scintillator: type of material that is able to convert non-visible, high-energy radiation into visible light. Can take many forms, including crystals or glass.

HOW THE SENSOR WORKS

Radiation particles enter the sensor and collide with the scintillator crystal. This collision of particles transfers energy from the radiation to the crystal. Once the particles collide with the crystal, the energy is converted into light. This light is captured by the electronic components of the sensor and converted into an electrical charge. This electrical charge is interpreted into a reading on the gamma detection device, usually in millisieverts or millirems. The more radiation particles that enter the sensor, the higher the electrical charge generated.

ADDITIONAL RESOURCES

OCCUPATIONAL HEALTH AND SAFETY

- Canadian Centre for Occupation Health and Safety - Radiation
- US Occupational Safety and Health Administration (OSHA) – Ionization Radiation: Control & Prevention
- US OSHA – Radiological Dispersal Devices (RDD) / Dirty Bombs

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

- Radiation Basics
- Radiation Terms and Units
- Radiation Sources and Doses
- Protecting Yourself from Radiation

ONLINE ENCYCLOPEDIAS

- Brittanica – Gamma ray
- Brittanica – Development and proliferation of atomic bombs
- Wikipedia – Gamma ray
- Wikipedia – Dirty bomb

AMERICAN CANCER SOCIETY

- What Are X-rays and Gamma Rays?
- Do X-rays and Gamma Rays Cause Cancer?
- How Are People Exposed to X-rays and Gamma Rays?

VIDEOS

- CrashCourse – Nuclear Physics: Crash Course Physics #45
- CrashCourse – Nuclear Chemistry: Crash Course Chemistry #48
- For the Love of Physics – What is a Scintillation Detector?

OTHER

- Australian Radiation Protection and Nuclear Safety Agency – Gamma radiation
- Bundesamt für Strahlenschutz (German Federal Office for Radiation Protection) – Limit values for occupationally exposed persons
- Canadian Nuclear Safety Commission – Protecting workers
- National Cancer Institute – Radiopharmaceuticals: Radiation Therapy Enters the Molecular Age
- Space.com – Gamma rays: Everything you need to know about these powerful packets of energy
- Stanford University Environmental Health & Safety – Maximum Permissible Occupational Doses
- Stanford University Scintillator Materials Group – Research Fundamentals
- United States Nuclear Regulatory Commission – Measuring Radiation
- US Office of Nuclear Energy – Advantages and Challenges of Nuclear Energy