# Radiation and Safety
# Unit3: Radiation detection and monitoring devices

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**Abstract**

Radiation Quantities and Units: Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, Annual Limit of Intake (ALI) and derived Air Concentration (DAC). Radiation detection: Basic concept and working principle of gas detectors (Ionization Chambers, Proportional Counter, Multi-Wire Proportional Counters (MWPC) and Gieger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators), Solid States Detectors and Neutron Detectors, Thermo luminescent Dosimetry.

## 1 Radiation Dose

A dose of medical radiation is not like a dose of medicine.

Radiation dose can be measured a number of ways.

Absorbed dose is used to assess the potential for biochemical changes in specific tissues. Equivalent dose is used to assess how much biological damage is expected from the absorbed dose. (Different types of radiation have different damaging properties.) Effective dose is used to assess the potential for long-term effects that might occur in the future. Definitions

Absorbed dose is the concentration of energy deposited in tissue as a result of an exposure to ionizing radiation i.e., energy absorbed by human tissue.

X-rays, unlike sunlight, can penetrate deep into the body and deposit energy in internal organs. X-rays can even pass through a person's body. Absorbed dose describes the intensity of the energy deposited in any small amount of tissue located anywhere in the body. The unit of measurement for absorbed dose is the milligray (mGy).

If you have a CT of your upper abdomen, the absorbed dose to your chest is very low, because it has only been exposed to a small amount of scattered radiation. The absorbed dose to your stomach, pancreas, liver and other organs is greatest, because they have been directly exposed.

Equivalent dose is an amount that takes the damaging properties of different types of radiation into account. (Not all radiation is alike.)

The difference between absorbed dose in tissue and equivalent dose:

Absorbed dose tells us the energy deposit in a small volume of tissue. Equivalent dose addresses the impact that the type of radiation has on that tissue. Because all radiation used in diagnostic medicine has the same low-harm potential, the absorbed dose and the equivalent dose are numerically the same. Only the units are different.

For diagnostic radiation: The equivalent dose in milliSievert (mSv) = the absorbed dose in mGy.

Effective dose is a calculated value, measured in mSv, that takes three factors into account:the absorbed dose to all organs of the body, the relative harm level of the radiation, and the sensitivities of each organ to radiation.

Effective dose: The quantity of effective dose helps us take into account sensitivity.

Different body parts have different sensitivities to radiation. For example, the head is less sensitive than the chest.

Effective dose relates to the overall long-term risk to a person from a procedure and is useful for comparing risks from different procedures. Effective dose is not intended to apply to a specific patient. The actual risk to a patient might be higher or lower, depending on the size of the patient and the type of procedure. For patients, the most important dose quantity is effective dose, because it allows for simple comparisons of long-term risks.

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Kerma, K, is expressed as the amount of energy released per mass of irradiated material and has the same unit as for dose, the gray (J/kg). Kerma differs from dose in that kerma is the energy released per mass, and dose is the energy absorbed per mass.

For occupational exposures, the 1990 recommendations of the International Commission on Radiological Protection (ICRP) limit the effective dose to 100 mSv in a 5 y period (giving an annual value of 20 mSv). The derived limit, ALI, for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year is the Annual Limit of Intake for a particular radionuclide and can be obtained by dividing the reference annual average dose of 20 mSv by the dose coefficient. (Publication 60 of the ICRP recommends an occupational committed effective dose limit of 20 mSv per year. For members of the public 1 mSv is the recommended value).

# 2 Radiation Detection

Nuclear radiation and x-rays are ionizing radiation and they can be detected from the ionizing events they produce.

## 2.1 Ionization Counters

Radiation detection can be accomplished by stretching a wire inside a gas-filled cylinder and raising the wire to a high positive voltage. The total charge produced by the passage of an ionizing particle through the active volume can be collected and measured. Different names are used for the devices based on the amount of voltage applied to the center electrode and the consequent nature of the ionizing events. If the voltage is high enough for the primary electron-ion pair to reach the electrodes but not high enough for secondary ionization, the device is called an ionization chamber. The collected charge is proportional to the number of ionizing events, and such devices are typically used as radiation dosimeters. At a higher voltage, the number of ionizations associated with a particle detection rises steeply because of secondary ionizations, and the device is often called a proportional counter. A single event can cause a voltage pulse proportional to the energy loss of the primary particle. At a still higher voltage, an avalanche pulse is produced by a single event in the devices called Geiger counters.

## 2.2 Scintillation Counters

Radiation detection can be accomplished by the use of a scintillator: a substance which emits light when struck by an ionizing particle. The scintillation detectors used in the Geiger-Marsden experiment were simple phosphor screens which emitted a flash of light when struck by an alpha particle. Modern scintillation counters may use single crystals of NaI doped with thallium. Electrons from the ionizing event are trapped into an excited state of the thallium activation center and emit a photon when they decay to the ground state. Photomultiplier tubes are used to intensify the signal from the scintillations. The decay times are on the order of 200 ns and the magnitude of the output pulse from the photomultiplier is proportional to the energy loss of the primary particle.

Some organic scintillators consist of a mixture of polystyrene and tetraphenyl butadine. They have the advantage of faster decay time (about 1 ns) and can be molded into experimentally useful configurations.

## 2.3 Particle Track Devices

Radiation detection can take the form of devices which visualize the track of the ionizing particle. Cloud chambers can show the track of a passing particle which can be photographed. D. A. Glaser's invention of the bubble chamber in 1952 largely replaced the cloud chamber. Placed in an intense magnetic field, the curvature of the tracks of the primary particles and their products give information about their charge and momentum.

Spark chambers can also visualize the tracks of particles and has the advantage that the paths can be recorded electronically.

## 2.4 Wire chamber

A multi-wire proportional chamber is a type of proportional counter that detects charged particles and photons and can give positional information on their trajectory, by tracking the trails of gaseous ionization.

Wire chamber with wires (W) and cathode () plates (P). The particles flying through T will ionize gas atoms and set free a charge that an amplifier (A) collects (impulse at the output). The multi-wire chamber uses an array of wires at high voltage (anode), which run through a chamber with conductive walls held at ground potential (cathode). Alternatively, the wires may be at ground potential and the cathode held at a high negative voltage; the important thing is that a uniform electric field draws extra electrons or negative ions to the anode wires with little lateral motion.

The chamber is filled with carefully chosen gas, such as an argon/methane mix, such that any ionizing particle that passes through the tube will ionize surrounding gaseous atoms. The resulting ions and electrons are accelerated by the electric field across the chamber, causing a localised cascade of ionization known as a Townsend avalanche. This collects on the nearest wire and results in a charge proportional to the ionisation effect of the detected particle. By computing pulses from all the wires, the particle trajectory can be found.

Adaptations of this basic design are the thin gap, resistive plate and drift chambers. The drift chamber is also sub-divided into ranges of specific use in the chamber designs known as time projection, microstrip gas, and those types of detectors that use silicon.

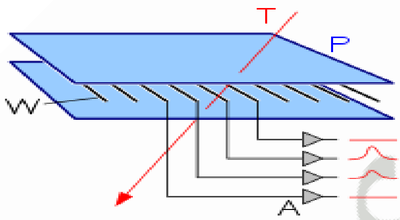


Figure 1: Photoelectric Effect

## 2.5 Geiger counter

The Geiger counter is an instrument used for detecting and measuring ionizing radiation. Also known as a Geiger-Mueller counter (or Geiger-Mller counter), it is widely used in applications such as radiation dosimetry, radiological protection, experimental physics and the nuclear industry.

It detects ionizing radiation such as alpha particles, beta particles and gamma rays using the ionization effect produced in a GeigerMller tube; which gives its name to the instrument. In wide and prominent use as a hand-held radiation survey instrument, it is perhaps one of the world's best-known radiation detection instruments.

## 2.6 Solid-state detector

Is the radiation detector in which a semiconductor material such as a silicon or germanium crystal constitutes the detecting medium. One such device consists of a p-n junction across which a pulse of current develops when a particle of ionizing radiation traverses it. In a different device, the absorption of ionizing radiation generates pairs of charge carriers (electrons and electron-deficient sites called holes) in a block of semiconducting material; the migration of these carriers under the influence of a voltage maintained between the opposite faces of the block constitutes a pulse of current. The pulses created in this way are amplified, recorded, and analyzed to determine the energy, number, or identity of the incident-charged particles. The sensitivity of these detectors is increased by operating them at low temperaturescommonly that of liquid nitrogen, 164 C (263 F)which suppresses the random formation of charge carriers by thermal vibration.

## 2.7 Neutron detection

Neutron detection is the effective detection of neutrons entering a well-positioned detector. There are two key aspects to effective neutron detection: hardware and software. Detection hardware refers to the kind of neutron detector used (the most common today is the scintillation detector) and to the electronics used in the detection setup. Further, the hardware setup also defines key experimental parameters, such as source-detector distance, solid angle and detector shielding. Detection software consists of analysis tools that perform tasks such as graphical analysis to measure the number and energies of neutrons striking the detector.

## 2.8 Thermoluminescent dosimeter

A thermoluminescent dosimeter, or TLD, is a type of radiation dosimeter. A TLD measures ionizing radiation exposure by measuring the intensity of visible light emitted by a crystal inside the detector when the crystal is heated. The intensity of light emitted is dependent upon the radiation exposure. Materials exhibiting thermoluminescence in response to ionizing radiation include calcium fluoride, lithium fluoride, calcium sulfate, lithium borate, calcium borate, potassium bromide, and feldspar. It was invented in 1954 by Professor Farrington Daniels of the University of Wisconsin-Madison.