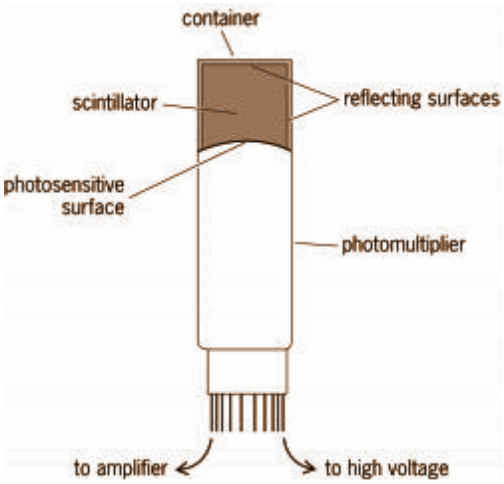
# Scintillation Counter

Scintillation Counter is an instrument that is used for measuring ionizing radiation. “It comprises of the scintillator that generates photons in response to incident radiation”, a PMT tube is used to convert an electronics and electric signal to process the signal.




A scintillation counter is used to detect gamma rays and a presence of a particle. It can also measure the radiation in the scintillating medium, the energy loss or the energy gain. The medium can either be gaseous, liquid or a solid. The scintillator counter is generally comprised of the transparent crystalline material such as glasses, liquids or plastics. One sector of the scintillators is placed (optical contact )with the pin code.

A charged particle loses energy when passing through the scintillator thus leaving the trail of excited molecules and atoms. A rapid interatomic transfer of electronic excitation energy follows, which leads to the burst of scintillator material ( luminescence characteristic. The scintillation response,  when a particle stops leading to the light output. The energy loss of a particle is measured when a particle passes completely through a scintillator.

## Applications of Scintillation Counter

1. Scintillation Counters are widely used in radioactive contamination, radiation survey meters,  radiometric assay, nuclear plant safety and medical imaging, that are used to measure radiation.
2. There are several counters of mounted on helicopters and some pickup trucks for rapid response in case of a security situation due to radioactive waste or dirty bombs.
3. Scintillation counters designed for weighbridge applications, freight terminals, scrap metal yards, border security, contamination monitoring of nuclear waste and ports.
4. It is widely used in Screening technologies, In vivo and ELISA alternative technologies, cancer research, epigenetics and Cellular research.

5. It also has its applications in  Protein interaction and detection, academic research and Pharmaceutical.
6. Liquid Scintillation Counter is a type of scintillation counter that is used for measuring the beta emission from the nuclides.

# Liquid scintillation counting

A liquid scintillation counter generally is not portable. Liquid scintillation counting is the most widely used technique for the detection and quantification of radioactivity. This measurement technique is applicable to all types of emissions, though it is most often used for beta particles. Liquid scintillation counting is an analytical technique that measures activity of radionuclides from the rate of light photons emitted by a sample.

Samples to be counted are prepared by adding a scintillation fluid (cocktail) to the beta emitter. As beta particles are released and interact with the fluid, photons of light are produced and measured. The intensity of the light is proportional to the energy of the beta particle; therefore, the spectra for different-energy beta emitters are somewhat unique.

Liquid scintillation counting (LS Counting) is a laboratory-based technique that uses a Liquid Scintillation Counter (LSC) to count the radioactive emissions from a liquid sample. It is often used in the biological sciences to measure the uptake of radioactive isotopes into biological materials. The different forms of an element are called isotopes.

For instance, the nucleus of the element phosphorus has 15 protons but it may contain differing numbers of neutrons. If it has 13 neutrons it is called $^{28}P$ (15 + 13 = 28) and if it has 19 neutrons it is called $^{34}P$. In fact phosphorus exists as 7 different isotopes:

$$^{28}P,\ ^{29}P,\ ^{30}P,\ ^{31}\mathbf{P},\ ^{32}P,\ ^{33}P,\ ^{34}P$$

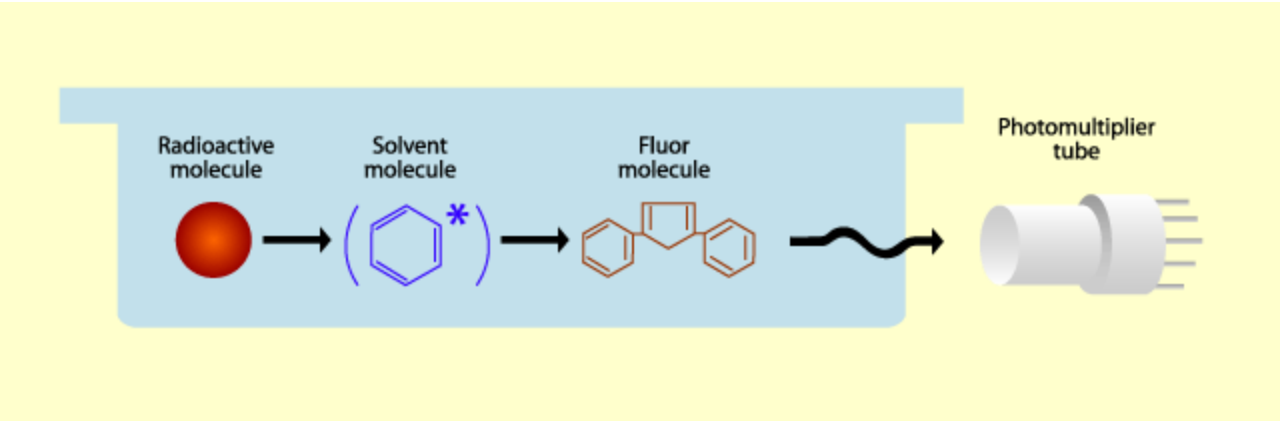
$^{31}\mathbf{P}$ is the most abundant form and is stable whereas the other isotopes may be unstable and emit radioactivity. In the case of $^{32}P$, a beta particle is emitted.

LSC is a method of counting radioactive emissions from a limited range of radionuclides. The common isotopes used include:

| Isotope | Half-Life | Decay |
|---|---|---|
| **$^{125}I$ (Iodine)** | 60 days | γ |
| **$^{3}H$ (Hydrogen also called tritium)** | 12.3 years | β |
| **$^{14}C$ (Carbon)** | 5730 years | β |
| **$^{35}S$ (Sulphur)** | 87.4 days | β |
| **$^{32}P$ (Phosphorus)** | 14.3 days | β |

Notice that all except $^{125}I$ are beta emitters. Beta emissions are often low or very low energy and although the emission can sometimes be detected by gamma radiation detection equipment such as a Geiger-Mueller Counter, the energy can easily be absorbed by the compound itself, by the surroundings and covers on detection equipment.

Liquid scintillation counting was developed to detect these low energy beta emitters.




The beta decay electron emitted by the radioactive isotope in the sample excites the solvent molecule which in turn transfers the energy to the solute (called a fluor as it emits light). The fluor emits a photon of light that is detected by the photomultiplier tube and converted into an electric signal and detected by the apparatus.

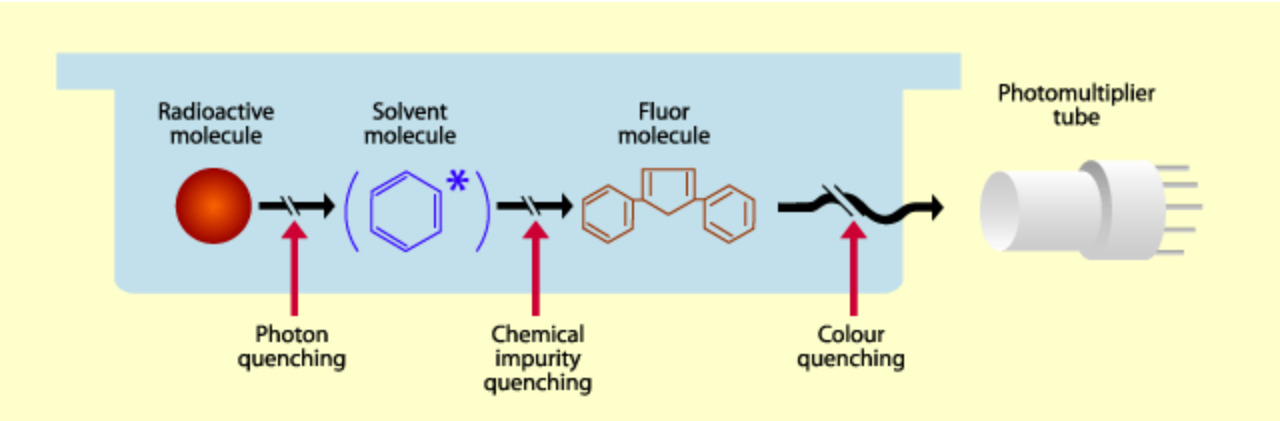
The sample is dissolved in a liquid scintillation cocktail that is typically composed of the following components:

| Component | Reason | Example of a component |
|---|---|---|
| **Solvent** | To solubilise the fluor and the sample. | Toluene, xylene, pseudodocumene |
| **Emulsifier** | A detergent to ensure proper mixing of aqueous samples. | Triton X-100 |
| **Fluor** | Emits light photon when excited by a beta particle. | PPO, POPOP |

There are many commercially available LS cocktails that are more environmentally friendly and contain less hazardous solvents than those listed above. Many are formulated to allow up to 40% v/v addition of sample to the cocktail.

**Interfering Processes**
There are a number of physical processes that may disrupt LSC. These include:

| Process | Explanation | Examples | Reduce Problem By |
|---|---|---|---|
| **Chemiluminescence** | Spurious generation of light due to chemical processes. | Bleaching agents, dioxane-based scintillators | Equilibrate sample for a period of time in the LSC |
| **Photoluminescence** | Emission of photons from excited molecular species. | Vials, caps, other materials in the LSC. Some samples such as proteinaceous materials when dissolved in alkaline solubilisers such as hyamine. | Acidify samples; avoid exposure to sunlight or fluorescent lighting. Dark adapt samples for several hours before counting. |
| **Background** | Radioactivity that does not arise from the sample. | Chance coincidence, cosmic rays, Cerenkov radiation, natural radioactivity such as thorium, potassium-40 and uranium. | Using appropriate blanks to correct for background. |
| **Quenching** | Reduction in the scintillation count rate. | Photon quenching, chemical impurity quenching, colour quenching (see diagram below). | Use Internal Standards to account for quenching. A standard with a known CPM/DPM is added and measured and the reduction due to quenching adjusted for in the measured samples. |




The output of the LSC is either in CPM or DPM.

**CPM** (Counts per minute) - gives a raw value for the number of radioactive events measured per minute. Often the sample is counted for a longer period (5 – 10 minutes) to account for any aberrations in shorter counts due to the radioactive events being a random process.

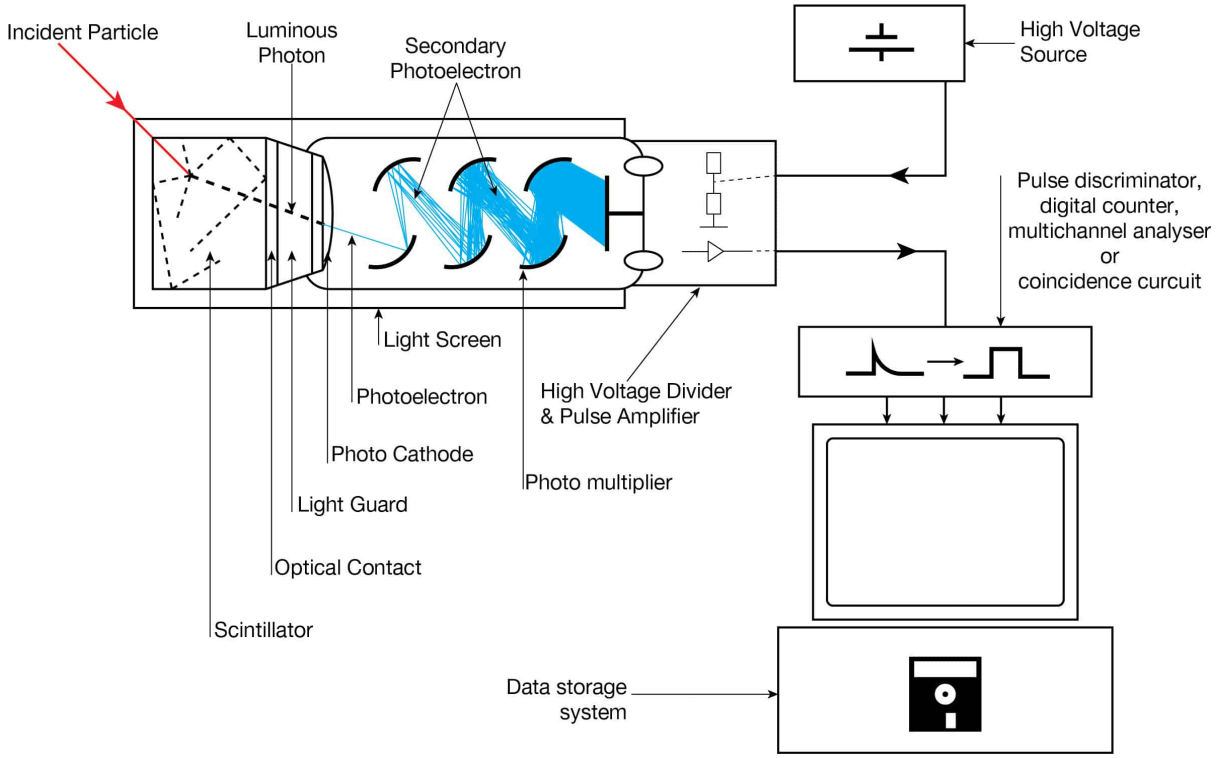
**DPM** (Disintegrations per minute) - adjusted CPM value to take into account the efficiency of the LSC. For instance, the LSC does not count all radioactive disintegrations as they occur in all three dimensions around the sample container and the detector is not able to measure them all.

***Examples of the use of LS Counting***

1. ***Viral Proteins:*** Proteins produced by viruses when they infect a cell are produced in very small amounts and are difficult to detect and purify. If virus-infected cells are fed a radioactive amino acid, then each time that amino acid is linked to form the growing protein a radioactive 'label' is attached to the protein. This radioactive 'label' is then used to monitor the identification and purification of the viral protein. Amino acids containing $^{3}H$, $^{14}C$ and $^{35}S$ are often used to label proteins. $^{35}S$ is particularly useful as sulphur is only found in two amino acids – methionine and cysteine.

2. ***Environmental Monitoring:*** Checking for $^{3}H$ spills in the laboratory. Tritium is such a weak emitter that its presence cannot be detected by a Geiger-Mueller counter. Wipe testing is usually used. This is where suspect surfaces are wiped with a piece of tissue. The tissue is placed in LS Cocktail in a LS vial and counted in the LS Counter.

# Solid Scintillation Counter – Principle of Operation




Apparatus with a scintillating crystal, photomultiplier, and data acquisition components.

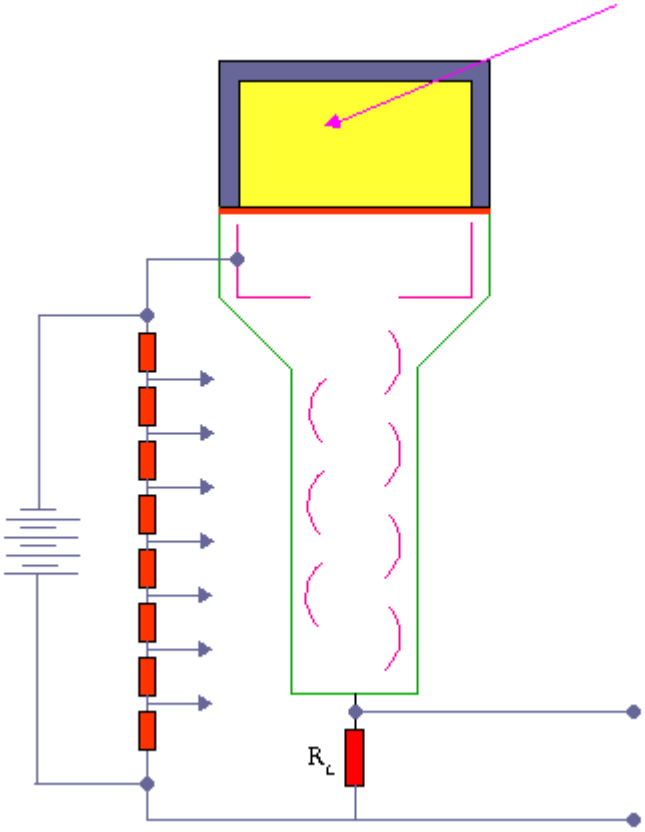
A **scintillation counter** or **scintillation detector** is a radiation detector which uses the effect known as **scintillation**. Scintillation is a **flash of light** produced in a transparent material by the passage of a particle (an electron, an alpha particle, an ion, or a high-energy photon). Scintillation occurs in the scintillator, which is a key part of a scintillation detector. In general, a scintillation detector consists of:

- **Scintillator**. A scintillator generates photons in response to incident radiation.
- **Photodetector**. A sensitive photodetector (usually a photomultiplier tube (PMT), a charge-coupled device (CCD) camera, or a photodiode), which converts the light to an electrical signal and electronics to process this signal.

The basic principle of operation involves the radiation reacting with a scintillator, which produces a series of flashes of varying intensity. The intensity of the flashes is proportional to the energy of the radiation. This feature is very important. These counters are suited to measure the energy of gamma radiation (**gamma spectroscopy**) and, therefore, can be used to identify gamma emitting isotopes.

## Scintillation Counter – Principle of Operation

The operation of scintillation counters is summarized in the following points:




- Scintillation Counter – Principle of Operation.
- Ionizing radiation enters the **scintillator** and interacts with the scintillator material. This cause electrons to be raised to an **excited state**.
  - For charged particles the track is the path of the particle itself.
  - For gamma rays (uncharged), their energy is converted to an energetic electron via either the photoelectric effect, Compton scattering or pair production.
- The excited atoms of the scintillator material **de-excite** and rapidly **emit a photon** in the visible (or near-visible) light range. The quantity is proportional to the energy deposited by the ionizing particle. The material is said to fluoresce.
- Three classes of phosphors are used:
  - inorganic crystals,
  - organic crystals,
  - plastic phosphors.
- The light created in the scintillator strikes the **photocathode** of a **photomultiplier tube**, releasing at most one photoelectron per photon.
- Using a voltage potential, this group of **primary electrons** is electrostatically accelerated and focused so that they strike the first **dynode** with enough energy to release additional electrons.
- These **secondary electrons** are attracted and strike a second dynode releasing more electrons. This process occurs in the photomultiplier tube.
- Each subsequent dynode impact releases further electrons, and so there is a current amplifying effect at each dynode stage. Each stage is at a higher potential than the previous to provide the accelerating field.
- Primary signal is multiplied and this amplification continues through 10 to 12 stages.
- At the **final dynode**, sufficient electrons are available to produce a **pulse** of sufficient magnitude for further amplification. This pulse carries information about the energy of the original incident radiation. The number of such pulses per unit time also gives information about the intensity of the radiation.