

Technique for detecting radioactive

- Liquid Scintillation
- Gamma Scintillation
- Positron Emission Tomography
- Radiochromatography

Liquid Scintillation Counting

Overview

- LSC is the most common technique for the measure of radioactivity of low energy beta emitter.
- The Sample is dissolved in counting solution.

The Scintillation Process

Scintillation Counting 1

Liquid Scintillation Cocktail

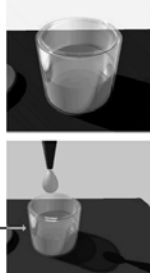
Components:

Solvent: Typically toluene, xylene, pseudocumene, or an alkyl benzene type solvent.

Emulsifier: A detergent type molecule that ensures proper mixing of aqueous samples.

Fluor: A fluorescent solute.

Process: Radioactive Sample is added to scintillation cocktail.



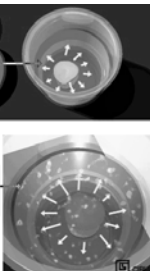
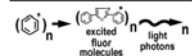
The Scintillation Process

Scintillation Counting 2

Beta particles are emitted, which cause solvent molecules to become excited.



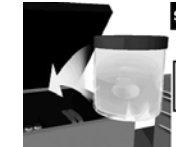
The energy of the solvent molecules is transferred to the fluor molecules, which in turn emit light.



The Scintillation Process

Scintillation Counting 3

The jar is placed inside a scintillation counter, which captures and digitizes the light photons.



photomultiplier tube



The Liquid Scintillation Cocktail: Solvent and solute

- This mixture is designed to capture the beta emission and transform it into a photon emission which can be detected via a photomultiplier tube within a scintillation counter.
- The cocktail must also acts as a solubilizing agent, keeping a uniform suspension of the sample.
- The scintillation counting system consists of 3 primary components:
 - The radioactive substance
 - The solvent
 - The solute or Fluor

Solvent

- The solvent will capture the energy of beta particle
- The solvent molecule achieves an excited state, and the excess energy is transferred from solvent molecule to solvent molecule
- The solvent tends to remain in an excited state for an extended period of time, decaying into the ground state without the emission of light
- Thus, Solvents tend to have a low quantum fluorescent yield**

Liquid Scintillation solvent

Liquid Scintillation Solvents				
solvent	relative pulse height *	quantum yield	decay time	average fluorescence wavelength (nm)
Benzene	0.85	0.07	29	283
Fluorobenzene	0.67	0.13	7.6	285
Toluene	1.00	0.17	34	285
<i>m</i> -Xylene	1.09	0.17	31	289
<i>o</i> -Xylene	0.98	1.19	32	289
<i>p</i> -Xylene	1.12	0.40	30	291

*Measured at a fixed concentration of PPO (3 g/L)

Solute

- ❖ Solutes (or fluors) exhibit properties which in many respects are just the opposite of those of solvents.
- ❖ They tend to decay rapidly mainly through the emission of light photons, thus having a high quantum fluorescent yield.
- ❖ Solutes that directly absorb the excitation energy of the solvent are also known as **primary solutes**.
- ❖ **Secondary solutes** were added to amplify the primary emissions.
- ❖ Secondary solutes were also complex organic compounds with the ability to absorb the decay energy of the primary solute and rapidly emitting it at a longer wavelength, shifting the overall signal to a wavelength more easily detectable by photomultiplier tubes.
- ❖ As more sensitive photomultiplier tubes were constructed, secondary solutes became unnecessary. However, they may still be used to improve counting efficiency, as both the shorter and longer wavelengths can be detected.

Photomultiplier tube

- ❖ The emitted light causes the emission of photoelectrons from the PMT which are multiplied by the PMT into a measurable electrical pulse.
- ❖ The amplitude of the pulse is proportional to the number of photons which interact in the PMT.
- ❖ The pulse height at the output of the PMT is proportional to the energy of the beta particle in the sample.
- ❖ These pulse can be analyzed to provide the energy of the beta particle and the rate of beta emission in the sample.
- ❖ Also possible to count very low energy gamma emitters by LSC since most of the gammas are absorbed in the counting solution.

Quenching

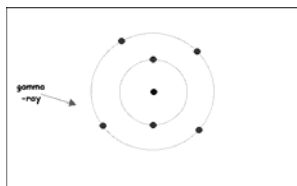
- ❖ A reduction in the total photon output of a sample resulting from a reduction in energy transfer efficiency.
 - ❖ 4 basic types of quenching
 - Impurity : strong inorganic acids, oxidizing agent, some organic compounds
 - Color : chlorophyll, hemoglobin
 - Dilution : insufficient number of fluor molecules
 - Absorption : heterogeneous samples
- <http://www.uwm.edu/Dept/EHSRM/RAD/HANDOUT.pdf>

Gamma Scintillation Counting

Gamma Radiation

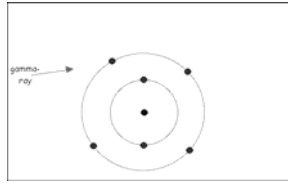
- Gamma ray photons often arise as a result of other decay processes (series decay) to rid the newly formed nucleus of excess energy.
- They have no mass and produce little if any direct ionization by collision along their path.
- Gamma photons are absorbed for detection and quantitation by one or more of three mechanisms: **the photoelectric effect, The Compton effect, and pair production.**

Photoelectric Effect



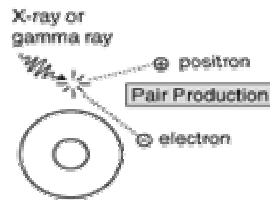
- The gamma ray interacts with an orbital electron, transferring all its energy to the electron and disappearing in the process.
- The photoelectric effect is the predominate interaction at low gamma ray energies (less than 0.5 MeV)

Compton Effect



- Gamma ray of medium energy (0.5-1.5 MeV) can undergo elastic collisions with orbital electrons.
- The gamma ray will transfer part of its energy to the electron and proceed in a new direction, at a lower energy (longer wavelength)
- The scattered photon has an energy which is dependent on its angle of emission and on the incident photon energy

Pair Production



- ❑ Can only occur when the energy of the photon exceeds 1.02 MeV
- ❑ Photon interacts with electric field of the nucleus; energy transformed into an electron-positron pair
- ❑ Of no consequence in diagnostic x-ray imaging because of high energies required

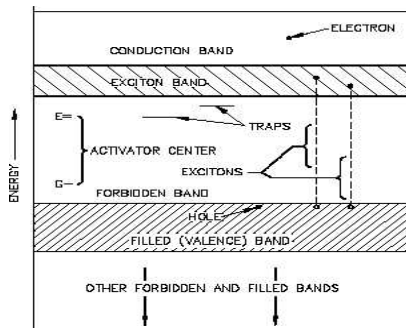
Gamma Scintillation Detector

- ❑ Scintillators can be made of a variety of materials, depending on the intended applications.
- ❑ The most common scintillators used in gamma-ray detectors which are made of **inorganic materials** are usually an alkali halide salt, such as NaI or CsI.
- ❑ To help these materials do their job, a bit of impurity is often added. This material is called an 'activator'. Thallium and sodium are often used for this purpose.
- ❑ So one often sees detectors described as NaI(Tl), which means it is a sodium iodide crystal with a thallium activator, or as CsI(Na), which is a cesium iodide crystal with a sodium activator.
- ❑ Tl and Na is used to shift the wavelength of the photon emitted by the excited molecule to a value which is not absorbed by the crystal

The scintillation process

- In a solid-state sense, a gamma-ray interacting with the crystal moves electrons from the valence band (by ionization of the molecules) to the conduction band.
- Band theory

Band Theory



Photomultiplier tube

- The output pulse is proportional to the number of photoelectrons originally released by the photocathode which is proportional to the number of photon produced in scintillator.
- The number of photons produced in the scintillator is proportional to the energy deposited in the scintillator by the Gamma radiation

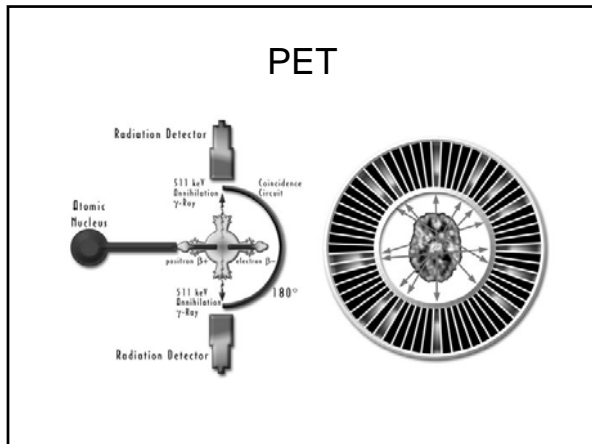
Positron Emission Tomography

What is it?

- PET is a technique used in clinical medicine and biomedical research to create images that show anatomical structure as well as how certain tissues are performing their physiological function.
- Functional imaging is the major

How does PET work?

- The radioisotopes used in PET have very short half lives compared to conventional nuclear medicine radioisotopes (in the order of minutes).
- PET radioisotopes emits a positron (a positively charged electron) in the process of decay. When this positron collides with an electron, the 2 particles annihilate each other, and produce 2 photons traveling in opposite directions.
- Two detectors positioned opposite one another can be used to detect the event.
- Many such events are collected in computer memory, and are used to make up a 3 dimensional image of the original distribution of tracer within the patient.



PET

- The most common radiopharmaceutical or tracer used in clinical PET imaging is 2-18F-deoxy-D-glucose (FDG).
- This is transported into the cell like normal glucose, but cannot be metabolized after initial metabolism, and is trapped within the cell.
- The greater the uptake of the FDG in the cell, the more metabolically active it is.

Detector

- Scintillation crystal of Bismuth germanate (BGO) to capture the annihilation photon.
- PMT to amplify the signal generated by the BGO annihilation photon capture and convert it into an electric signal.
- Detection/Coincidence circuitry to assure that the photon which caused the signal is actually an annihilation photon

Radiochromatography

- Various technique and devices have been developed for combining the elegant separation capability of chromatographic systems with the high sensitivity and selectivity inherent in measuring radiolabeled drugs and metabolites.

TLC

- The simplest (and cheapest) procedure is to scrape narrow bands of the thin layer material into individually tubes, then each tube being counted for an appropriate period of time in scintillation counter
- The alternative procedure is by scanning the TLC plate with the detector which registers radiation passing through a narrow slit.

TLC

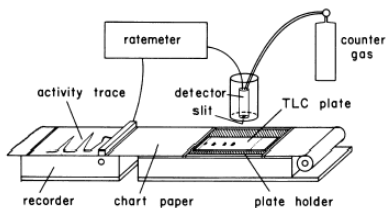


Figure 7.1 TLC radiochromatogram scanner system. For clarity the structure supporting the detector has been omitted. System shown has a gas flow detector for b- -emitting nuclides. For g-emitting nuclides this detector may be replaced by a crystal scintillation detector.

TLC

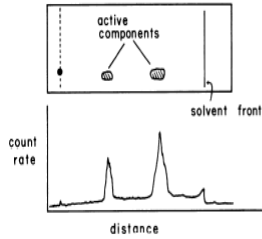


Figure 7.2 Typical radiochromatogram obtained using a scanner system, shown adjacent to the TLC plate. Small peaks at the sample application point and at the solvent front are common, and in fact can be useful for alignment of the TLC plate with the radiochromatogram

GC

- By the addition of a suitable detector to monitor the activity of the column effluent

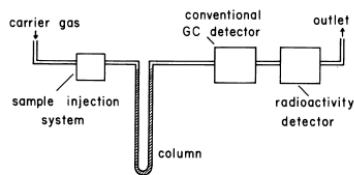


Figure 7.3 Schematic arrangement of major elements of a radiogas chromatograph

GC

- The main problem arises because most radioactivity detectors are not suitable for operation at the **high temperature used for GC separations.**
- For example, most gas ionization detectors cannot be operated satisfactorily at temperature above 100 C and PMT used in Gamma scintillation detectors become electronically noisy above RT.

GC

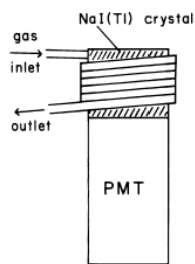


Figure 7.4 Simple g detector for radiogas chromatography. Note that this arrangement is not particularly efficient and is unsuitable for use above room temperature. For clarity, shielding has been omitted

HPLC

- ❖ Radiolabeled compounds separated by HPLC can be measured for activity by "collecting and analyzing peaks" by liquid scintillation counting.
- ❖ Liquid flow-through counters that are useful for measuring carbon-14-labeled drugs and metabolites eluted from an HPLC column have been described.
- ❖ However, an HPLC detector for determining carbon-14- and tritium-labeled solutes has yet to become available commercially.
- ❖ On the other hand, if the chromatography cools to significantly below the boiling point of an eluted component, peak tailing or even condensation within the detector may cause serious difficulty.

- ❖ <http://crac3.ch.kcl.ac.uk/kclchem/courses/djmlirc/irc7.pdf>
- ❖ http://www.bh.rmit.edu.au/mrs/DigitalRadiography/DRPapers/DEXA_ScintDetectors.html
- ❖ http://laxmi.nuc.ucla.edu:8248/M248_99/autorad/Scint/scint1.html
- ❖ http://www.rah.sa.gov.au/nucmed/PET/pet_info.htm
- ❖ <http://nucleus.wpi.edu/Reactor/Labs/R-scin.html>
- ❖ <http://www.uwm.edu/Dept/EHSRM/RAD/HANDOUT.pdf>
