Detectors

szerző: PGY

Sample containers

Use common sense!

The container must allow the sample to pass through to the detector.

For liquid scintillation, it must allow the light that is produced to pass through.

Don't use contaminated containers

Typically use disposable ones.

Errors and Their Correction

Counting errors can result from a number of sources including:

Statistical
Background
Detector resolution
Counter resolution
Counting efficiency
Absorption of radiation
Geometry

Statistical errors

Radioemission is random by nature.

It is impossible to predict when any nuclide will decay.

To account for this, we must rely on:

- Measuring a large number of disintegrations.
- Application of the laws of probability.

Statistical errors

A straightforward approach would be to make a large number of measurements.

$$\bar{x} = \frac{\sum x_i}{n}$$

This is not practical if:

Nuclide half-life is short.

Counting time is long (low activity).

Statistical errors

Statistical errors can be accounted for by assuming that for one measurement:

$$\sigma_A \simeq \sqrt{A}$$

So at the 95% confidence level :

$$\text{value} \simeq A \pm 2\sqrt{A}$$

So as the value of A increases, the relative value of $\pm\ 2\ A^{1/2}$ decreases.

Statistical errors

Activity	$2\ A_{1/2}$	% error
10	6.3	63
100	20	20
1000	63	6.3
10000	200	2
100000	632	0.63

Statistical errors

If you want < 2% relative error with a single reading, you must have > 10,000 counts.

You can:

Increase the counting time if half-life permits it.

Background is relatively constant.

Background

Each detector system will count a number of pulses even when no sample is present:

- Background radiation
- Spontaneous emission from the detector
- PM dark current
- Electronic noise

Background radiation is typically the major source of noise.

Background

Each type of detector has its own level of background.

Detector	Average total background, cpm
GM	10 - 12
NaI(Tl)	100 - 600
Liquid Scintillation	10 - 30
Ge(Li)	10 - 100

Background

The major source of background is naturally occurring radiation.

Much, but not all of it, can be eliminated by using adequate shielding of the detector.

We typically use so type of lead shielding.

At least one inch thick

Low activity lead

Background

Background will also vary with time so must be accounted for statistically.

It's best to measure background separately either just before or after counting your sample.

$$\text{measured count} = cpm_{sample} + cpm_{background}$$

Background

So, when we count our sample, it actually contains a sample and a background component - each with its one variance.

$$\sigma_{measured} = (\sigma^2_{sample} + \sigma^2_{bkg})^{1/2}$$

$$\sigma_{measured} = counts^{1/2}$$

Low background example

If background << sample activity - you only introduce a small error.

	cpm	σ	95% CL
Total	1200	34.6	5.6
Background	150	12.2	16.3
Sample	1050	36.7	7.0

Low background example

If it is >> sample activity - you have a real problem and large errors.

	cpm	σ	95% CL
Total	100	10	10
Background	80	8.9	11.2
Sample	20	4.5	22.5

Reducing background errors

You can reduce large background errors by:

Using a long count time for background

Using a discriminating detector and counting system

Working with ‘hotter’ samples.

Resolution errors

These occur when a sample is so active that the equipment can't keep up.

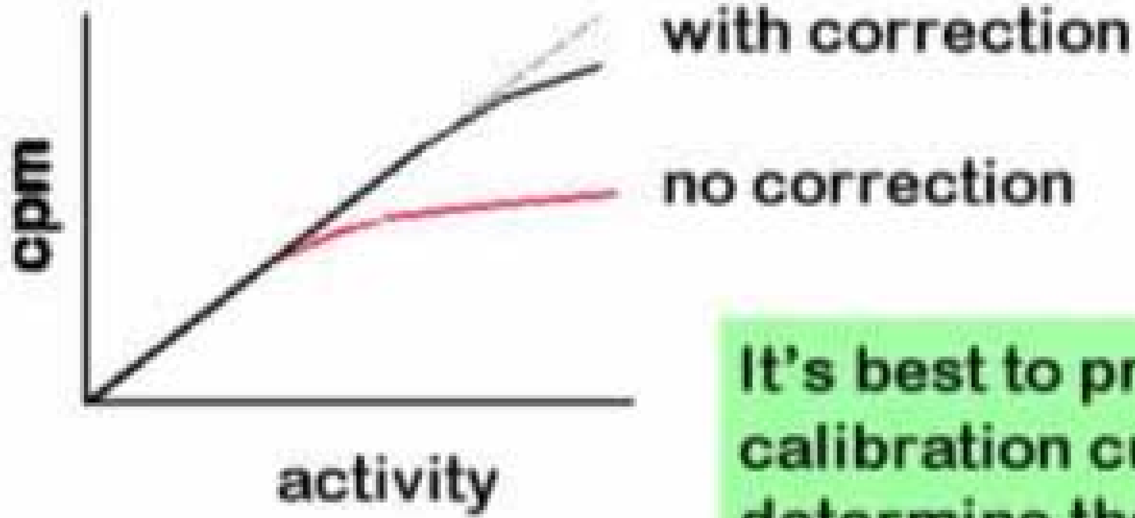
GM ~ 200 μs / count
NaI(Tl) ~ 2 μs / count

Simple scalers max out at about 10^6 cpm.

Analyzers are slower still.

Resolution errors

Live time correction can be used to reduce this effect but it has its limits.



It's best to produce a calibration curve to determine the effectiveness of the correction and its limits.

Detector efficiency

Most methods rely on using relative activities so efficiency is not a problem.

It is assumed that for any detection - counting system, the efficiency is a constant.

Efficiency is a concern for:

Absolute activity determinations.

Determining the amount of a tracer to use or purchase.

Detector efficiency

Since efficiency can vary with time and with the energy of the event being measured, it should be checked periodically.

The best way is to buy a calibrated standard - hopefully of the same nuclide and geometry.

$$\%\text{Efficiency} = 100 \frac{\text{counts observed}}{\text{disintegrations expected}}$$

Detector efficiency

Detector	Radiation	%Eff
2π proportional	α,β	10-50
GM	β	<1-30
	γ	<1
NaI(Tl)	γ	10-30
Liquid Scint.	β	50-100
Ge(Li)	γ	$\leq$ 10

Absorption of radiation

α absorption is greater than β.

γ typically is not a problem.

α and β can be absorbed by:

- The sample - matrix, solvent ...
- Sample container
- Detector

Absorption of radiation

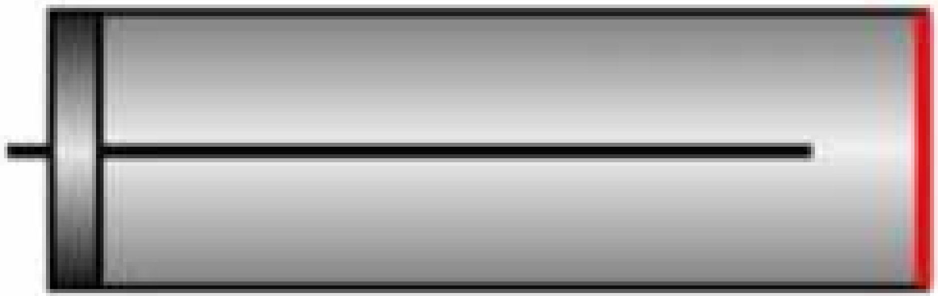
You can minimize the problems by:

Decreasing the sample solvent.

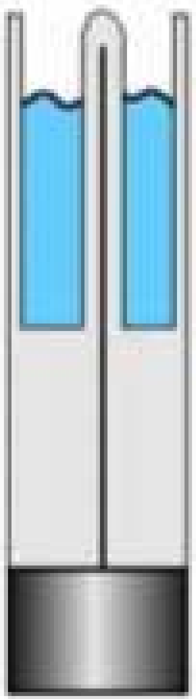
Using a thin wall container (or none).

Using a thin wall detector or putting the sample in the detector.

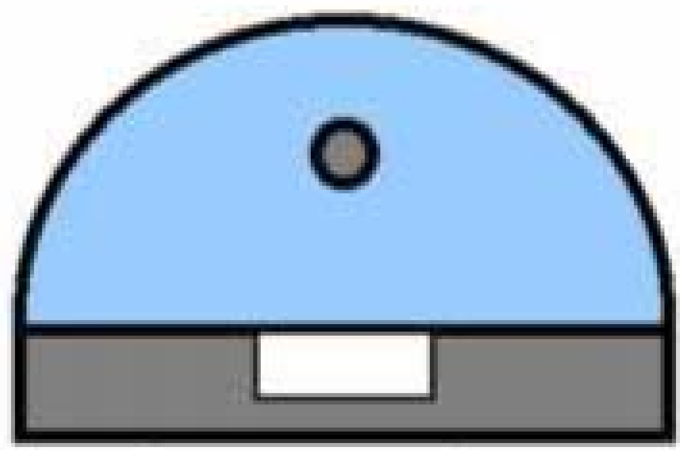
Absorption of radiation



Thin window GM tube



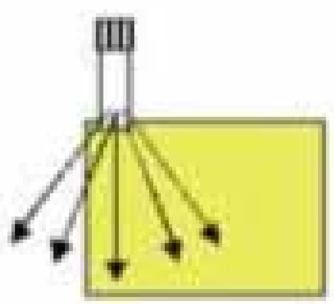
Thin walled GM tube for liquid samples

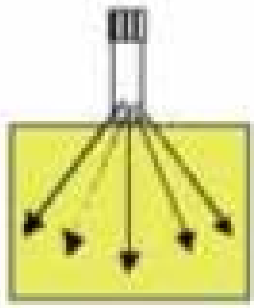


2π symmetry proportional counter

Geometry

Variations in sampling can occur based on how the sample is placed in or on the sample.





This is not a problem with submersed GM, liquid scintillation or well typeNaI(Tl) detectors.

Geometry

You can reduce this problem by using a sample holder.

Insures that your samples are

- The same distance from the detector
- Same location