

American National Standard Calibration and Usage of Alpha/Beta Proportional Counters

Sponsor

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Abstract: This standard establishes methods for the calibration and use of gas proportional counters with and without active guard detectors. This standard also establishes methods for measuring the alpha and beta counting plateau, crosstalk factors, background, alpha and beta efficiency from prepared standards, correction factors for samples whose self-attenuation or mass differs from that of the standard, and calculation of the sample activities together with their random and total uncertainties. Correction for pulse pileup due to high count rate is also discussed. Although many principles articulated in this standard apply to the counting of radionuclides emitting a maximum beta energy below 100 keV as well, the counting of these low-energy beta emitters requires a higher degree of attention to detail in sample preparation, instrument calibration, and measurement correction factors than addressed in this standard. Therefore, this standard is intended for measuring radionuclides with maximum beta energies above 100 keV.

Keywords: alpha/beta proportional counters, calibration

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Introduction

(This introduction is not part of ANSI N42.25-1997, American National Standard Calibration and Usage of Alpha/Beta Proportional Counters.)

This standard is the responsibility of the Accredited Standards Committee on Radiation Instrumentation, N42. Committee N42 delegated development of this standard to Subcommittee N42.RM. Drafts were reviewed by Committee N42, Subcommittee N42.RM, and other interested parties, and the comments received were utilized in producing the standard as finally approved. The standard was approved by N42 letter ballot of 18 March 1996.

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Contents

1. Overview.....	1
1.1 Scope.....	1
1.2 Special word usage	2
2. References.....	2
3. Definitions.....	2
3.1 Glossary	2
3.2 Symbols	5
3.3 Apparatus	5
4. Calibration.....	5
4.1 General.....	5
4.2 Detector plateau measurement.....	6
4.3 Discriminator settings	8
4.4 Background.....	9
4.5 Efficiency	10
5. Sources	11
5.1 Efficiency calibration sources.....	11
5.2 Check sources	11
6. Performance tests	12
6.1 Sources.....	12
6.2 Verification of counter background	12
6.3 Verification of alpha, beta, and guard plateau bias points.....	13
6.4 Verification of crosstalk (spillup/spilldown)	13
6.5 Effectiveness of guard detector.....	13
6.6 Verification of alpha and beta efficiency.....	14
6.7 Estimated uncertainty for gross alpha/beta screening.....	14
7. Determination of uncertainties and their propagation	15
8. Quality control and assurance	17
Annex A (informative) Preparation of working standards from standard solutions	19
A.1 Simple volumetric preparation of planchet style sources	19
A.2 Simple gravimetric preparation of planchet style sources	20
Annex B (informative) Guidance on measurement of samples	21
B.1 General precautions	21
B.2 Net count rates	21

B.3	Concentrations	23
B.4	Weight correction.....	24
B.5	Health physics smear samples	25
Annex C	(informative) Bibliography	26

American National Standard Calibration and Usage of Alpha/Beta Proportional Counters

1. Overview

This standard provides a basis for the routine calibration and use of gas proportional counters with or without active guard detectors. Gas proportional counters are used for the measurement of alpha and beta emission rates, and for the measurement of radionuclide activities when interferences from other radionuclides are not present. This standard is intended for use by persons who have an understanding of the principles of gas proportional counting and are responsible for the development of correct procedures for the calibration and use of these radiation measurement counters. References [B6], [B7], and [B11]¹ provide information on the principles of operation of alpha/beta proportional counters.

A typical alpha/beta gas proportional counter consists of one or more gas proportional counters, active guard detectors, associated counting gas, signal processing electronics, and a scaler, or a multi-channel analyzer to record the detected counts. Computers are commonly interfaced to these systems to provide computer control as well as to permit automatic correction for efficiency, self attenuation, and other sample specific factors, and for storage of quality assurance/quality control information. Automatic propagation of uncertainties is also provided by many commercially supplied computer-controlled instruments.

1.1 Scope

This standard establishes methods for the calibration and use of gas proportional counters with and without active guard detectors. This standard also establishes methods for measuring the alpha and beta counting plateau, crosstalk factors, background, alpha and beta efficiency from prepared standards, correction factors for samples whose self-attenuation or mass differs from that of the standard, and calculation of the sample activities together with their random and total uncertainties. Correction for pulse pileup due to high count rate is also discussed. Although many principles articulated in this standard apply to the counting of radionuclides emitting a maximum beta energy below 100 keV as well, the counting of these low-energy beta emitters requires a higher degree of attention to detail in sample preparation, instrument calibration, and measurement correction factors than addressed in this standard. Therefore, this standard is intended for measuring radionuclides with maximum beta energies above 100 keV.

¹The numbers in brackets correspond to those of the bibliography in Annex C.

1.2 Special word usage

The word *shall* denotes a requirement, the word *should* denotes a recommendation, and the word *may* denotes permission. To conform to this standard, gas proportional counting shall be performed in accordance with the requirements of this standard, but not necessarily with its recommendations. However, justification should be documented for deviations from a recommendation.

2. References

ANSI N42.14-1991, American National Standard Calibration and Use of Germanium Spectrometers for the Measurement of Gamma-Ray Emission Rates of Radionuclides.²

ANSI N42.22-1995, American National Standard Traceability of Radioactive Sources to the National Institute of Standards and Technology (NIST) and Associated Instrument Quality Control.

ANSI N42.23-1996, American National Standard Measurement and Associated Instrumentation Quality Assurance for Radioassay Laboratories.

3. Definitions

3.1 Glossary

3.1.1 active guard detector: A detector constructed from similar materials with similar geometry to the main sample counting detector. This detector is mounted in proximity to the sample counting detector in order to intercept and react to the same background cosmic and terrestrial radiation field as the sample detector. Normally this detector is used in an anti-coincidence mode to cancel out the effect of this background radiation field on the sample detector in order to produce a real-time adjusted net count rate for the sample detector.

3.1.2 activity: The expected number of spontaneous nuclear decays (transformations) in unit time from a specified energy state (excluding prompt decays from a lower nuclear level) for a given amount of a radionuclide. Its standard unit (SI) is the becquerel (Bq), where one Bq equals one decay per second. Activity is often also expressed in curies, where 3.7×10^{10} Bq equals one Ci exactly or in disintegrations per minute (dpm), where 1 dpm equals 1/60 Bq exactly.

3.1.3 alpha emission rate: The rate at which alpha particles of all energies are emitted from one or all alpha-emitting radionuclides present in a source or sample.

3.1.4 alpha surface emission rate: The rate at which alpha particles of all energies emanate from the surface of a source or sample that contains one or more alpha-emitting radionuclides.

3.1.5 attenuation: The net loss of radiation field from the sample resulting from scattering or absorption in the sample or in material between the sample and the active volume of the counting chamber.

3.1.6 background count rate: Events per unit time from radioactive decay not caused by a calibration source or sample but rather from that occurring in the surrounding environment or from cosmic-ray interactions in or adjacent to the detector that have escaped detection by the guard detector, when present.

²These ANSI N42 publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

Contributions to the background count rate can include naturally occurring radioactive decay in the structural materials comprising the counter, shielding, and cosmic-ray-induced ionizing radiation.

3.1.7 beta emission rate: The rate at which beta particles of all energies are emitted from one or all beta-emitting radionuclides present in a source or a sample.

3.1.8 beta surface emission rate: The rate at which beta particles of all energies emanate from the surface of a source or sample that contains one or more beta-emitting radionuclides.

3.1.9 blank count rate: Events per unit time from radioactive decay or cosmic-ray interactions in materials that make up the proportional counter, surrounding materials (background count rate), and the sample blank (consisting of the planchet and sample matrix). A sample blank may contain naturally occurring radionuclides and their daughter products.

3.1.10 check source: A radioactive source, not necessarily calibrated, which is used to confirm satisfactory operation of an instrument.

3.1.11 combined uncertainty: The uncertainty resulting from combining category A and category B uncertainties, as defined by the Bureau International des Poids et Mesures (BIPM) (see [B5]), using standard statistical methods. Category A uncertainties are evaluated by applying statistical methods to a series of repeated measurements and are characterized by the estimated standard deviation, s_A ; category B uncertainties are assigned to quantities whose variation is not explicitly observed. Category B uncertainties are determined by estimating from other information an approximation to a corresponding "standard deviation," s_B , whose existence is assumed. They are combined as if they are all standard deviations.

3.1.12 count rate: The rate at which detector pulses are being registered in a selected voltage interval. The unit is reciprocal seconds (i.e., s^{-1}) or reciprocal minutes (i.e., min^{-1}).

3.1.13 crosstalk: The fraction of all recorded pulses from alpha particles that are recorded in the beta channel due to degradation in their pulse height or the fraction of all recorded pulses from beta particles that are recorded in the alpha channel due to pulse pileup or other phenomenon. The beta crosstalk into the alpha channel should be negligible if the operation point (see definition) has been selected correctly. This term is equivalent to the term *spillup/spilldown*. Crosstalk is commonly used to indicate that the method of discrimination is pulse-height discrimination. *See also: spillup/spilldown.*

3.1.14 dead band: A region between the highest beta pulse and the lowest alpha pulse for a given radionuclide or mix of radionuclides that contains no pulses when using energy or rise time discrimination. Due to physical processes or electronic limitations this region may contain pulses not anticipated to be present.

3.1.15 interference or cross chamber interference: The fraction of all recorded pulses in either the alpha channel or the beta channel of a multiple chamber counting system that are due to the presence of a sample in an adjacent counting chamber.

3.1.16 measurements assurance program (MAP): A program that allows manufacturers to verify the accuracy of their measurements through exchange of samples with the National Institute of Standards and Technology (NIST). This involves the analysis of blind test samples sent to the suppliers by NIST, and NIST measurement of sources certified and provided by the supplier.

3.1.17 NIST: National Institute of Standards and Technology (formerly National Bureau of Standards, NBS).

3.1.18 NSLR: A country's National Standardizing Laboratory for radioactivity measurements.

3.1.19 operation point: The locations in channels or voltage settings of the lower-level and upper-level discriminators for each counting channel and when appropriate the setting of a dead band region to separate the alpha and beta counting regions by pulse height or by rise time discrimination.

3.1.20 P-10 counting gas: A gas mixture commonly used in alpha/beta counters consisting of approximately 10% methane and 90% argon.

3.1.21 pulse pileup: Occurrence of two or more successive pulses closely associated in time but from separate decays such that they contribute to each other's height and shape. Usually the system processes the multiple inputs as a composite single pulse. Pulse pileup is a function of the amplifier pulse width and of the square of the count rate. *Syn:* random summing.

3.1.22 radioactive sample: A sample containing one or more radionuclides whose activity, activity concentration, emission rate or surface emission rate of ionizing radiation is to be measured.

3.1.23 radioactive source: A sample containing one or more known radionuclides whose activity, activity concentration, or emission rate of ionizing radiation may be but is not necessarily known.

3.1.24 spillup/spilldown: The fraction of all recorded pulses from alpha particles that are recorded in the beta channel due to their long rise time or the fraction of all recorded pulses from the beta particles in the alpha channel that are recorded due to their short rise time. This term is equivalent to the term crosstalk. Spillup/spilldown is commonly used to indicate that the method of discrimination is rise time (pulse shape) discrimination. *See also:* **crosstalk**.

3.1.25 total alpha emission rate: The rate at which alpha particles of all energies are emitted from alpha-emitting radionuclides present in a source or sample.

3.1.26 total beta emission rate: The rate at which beta particles of all energies are emitted from beta-emitting radionuclides present in a source or sample.

3.1.27 traceability: The ability to relate the measurement accuracy of radionuclide sources to national physical standards. Traceability is achieved by demonstrating the capability to produce accurate standardized sources by participation in a Measurements Assurance Program (MAP) with linkage to the National Institute of Standards and Technology (NIST) and production of certified materials in accordance with a quality assurance program that meets the guidance provided in this standard. Traceability of sources requires demonstrated measurement traceability as described in 8.3 of [B7] and in Clause 6 of ANSI N42.22-1995³ and applies only to products produced in accordance with the procedures described in ANSI N42.22-1995.

3.1.28 ultra-high purity counting gas: In the case of P-10 counting gas, 99.999% pure argon, and 99.97% pure methane.

3.1.29 uncertainty: The likely inaccuracy of a reported value, expressed in terms of estimated standard deviations. *See also:* **combined uncertainty**.

3.1.30 window width: The difference, expressed in volts or energy (keV or MeV), between the lower-level and upper-level pulse-height discriminator settings.

3.1.31 working standard: Various prepared samples containing a known activity concentration of a radionuclide and traceable to a known National Institute of Standards and Technology (NIST) physical standard.

³Information on references can be found in Clause 2.