



LAB 26

EDITION 2 | OCTOBER 2004

CALIBRATION OF RADIONUCLIDE SOURCES

Activity, Particle or Photon Emission Rate,
Air Kerma Rate

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CHANGES SINCE LAST EDITION

Changes from previous edition are indicated by a marginal line.

1 INTRODUCTION

- 1.1 Laboratories that have been assessed by UKAS as meeting the requirements of ISO/IEC 17025 *General Requirements for the Competence of Testing and Calibration Laboratories* may be granted UKAS Accreditation. Several guidance publications on the application of these requirements, providing extra information, detail and limitations are listed in UKAS *Publications (M4)*.
- 1.2 This publication (LAB 26) provides guidance on the application of specific requirements for laboratories carrying out the calibration of radioactive sources in respect of activity, α , β , γ , X-ray or conversion electron emission rate, neutron emission rate or exposure/kerma rate. By following this guidance, laboratories will be able to demonstrate at assessment that they meet the requirements. Alternative methods may be used provided they are shown to have an equivalent outcome.
- 1.3 The guidance applies to such specific types of source as may be supplied by the laboratory or the organisation of which the laboratory may be part, according to a list submitted to UKAS before accreditation. It also applies to those sources of the same type which are submitted to the Laboratory by a third party for the purposes of being similarly standardised. Any subsequent addition to the list of approved types of source would require specific approval. The specific types of source should conform to the following general categories:
- (a) standardised solutions to be calibrated in terms of activity;
 - (b) solid sources to be calibrated in terms of activity;
 - (c) radium-226 sources to be calibrated in terms of radium element content;
 - (d) sources to be calibrated in terms of γ -ray, or X-ray emission rate;
 - (e) sources to be calibrated in terms of α -particle, β -particle or conversion electron emission rate;
 - (f) sources to be calibrated in terms of neutron emission rate;
 - (g) photon-emitting sources to be calibrated in terms of air kerma rate.
- 1.4 The laboratory should provide written procedures for sample preparation and measurement for each source type and radionuclide.
- 1.5 As far as possible, calibration procedures for the absolute determination of activity should be based upon the $4\pi\beta$ - γ coincidence method (including closely related methods, eg, $4\pi\alpha$ - γ coincidence counting, $4\pi\beta$ - γ coincidence tracer efficiency technique, etc). Section 2 relates specifically to the $4\pi\beta$ - γ coincidence method. Other methods (including extensions of the $4\pi\beta$ - γ coincidence method) for absolute determination of activity would need specific approval and verification.

2 ABSOLUTE STANDARDISATION OF RADIONUCLIDE SOLUTIONS

2.1 Materials

2.1.1 All sources are supplied by the Laboratory, all materials intended for incorporation into radionuclide solutions should be ordered against written specifications and/or be subject to quality control examination and verification. All equipment used in source preparation shall be of suitable material and quality for the intended purpose. Where sources are supplied by a third party, that third party should be asked to provide as much information as possible in order to ensure that, where possible, the same level of quality control can be exercised.

2.2 Dispensing

2.2.1 The following requirements apply to the dispensing of radionuclide solutions:

- (a) all containers should be of an appropriate type and specification;
- (b) all containers and other glassware should be cleaned by an appropriate procedure;
- (c) carrier solutions should be prepared in advance and should be filtered to remove suspended solids; carrier solutions should be stored in appropriate containers;
- (d) sufficient calibration containers should be prepared to provide an independent check on all dilutions (see paragraph 2.4.1);
- (e) equipment used for gravimetric or volumetric measurements should be calibrated in a manner traceable to national standards. Weighings are subject to buoyancy corrections, as appropriate.

2.3 Radionuclide Purity

2.3.1 Radionuclide purity should be assessed by appropriate means and verified.

2.4 Ionisation Chamber Check Measurements

2.4.1 Where possible, calibration containers of γ -ray emitting solutions of sufficient activity should be checked by measurement in a transfer instrument that has been calibrated in a manner traceable to national standards. The preferred transfer instrument, because of its long-term stability, is a well-type, sealed high-pressure ionization chamber. Alternative instruments such as gamma spectrometers or liquid scintillation counters may be employed but additional quality control measures may be necessary because of their susceptibility to short-term variations in response.

2.5 Source Preparation

2.5.1 Where solid sources are required for $4\pi\beta\text{-}\gamma$ coincidence counting, the following criteria apply:

- (a) sources should be prepared by dispensing gravimetrically solutions of appropriate dilution onto thin conducting plastic films supported on metal rings, followed by evaporation to dryness;

- (b) sufficient sources should be prepared from each dilution to demonstrate consistency within the required specification;
- (c) when volatile material is involved due precautions should be taken to avoid loss of activity by evaporation.

2.6 4pb-g Coincidence Measurements

2.6.1 Where the $4\pi\beta\text{-}\gamma$ coincidence method is used to determine the absolute activity of the solution, the following criteria apply:

- (a) the equipment used should be of the conventional type, comprising a well-shielded system containing a suitable β -particle detector, such as a gas-flow proportional counter or a liquid scintillation counter, together with one or more NaI detectors or other suitable γ -ray detectors, used in conjunction with appropriate electronic units;
- (b) in this context, the " β " term is an abbreviation which includes such emissions as beta particles, alpha particles, positrons, conversion and Auger electrons and photon emissions of sufficiently low energy that they are detected in significant quantities;
- (c) the observed counting rates should be corrected where necessary for the following:

Deadtime
Background
Resolving time
Half-life.

Other corrections should be applied where appropriate, such as those for the γ -(β -) ray efficiency of the β -(γ -) ray counter, and for the decay scheme of the radionuclide.

2.7 Variations of the 4pb-g Coincidence Method

2.7.1 At the discretion of UKAS, the absolute determination of activity for specific radionuclides may be accomplished by variants of the $4\pi\beta\text{-}\gamma$ coincidence method, such as:

- (a) the efficiency-tracing technique;
- (b) the computer-discrimination method;
- (c) correlation counting;
- (d) multi-dimensional extrapolation;
- (e) anti-coincidence counting.

2.8 Traceability

2.8.1 The $4\pi\beta\text{-}\gamma$ coincidence counting measurements made by the laboratory should be traceable to national standards. Traceability should be established and maintained through the regular exchange and measurement of a representative range of radionuclide samples with the national metrology institute. In the case of a national metrology institute, comparison programmes should be established and maintained with other national metrology institutes via Key Comparisons as prescribed by the

Mutual Recognition Arrangement. MRA: *Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes*, International Committee for Weights and Measures, 1999, 45 pp. <http://www.bipm.org/pdf/mra.pdf>.

3 SOLUTION SOURCES

- 3.1 Solutions (including gas standards) of β - γ emitting radionuclides may be calibrated by either of the following methods:
- (a) absolute standardisation by the $4\pi\beta$ - γ coincidence method or an agreed variant thereof;
 - (b) secondary standardisation by means of a transfer instrument that has itself been calibrated in a manner traceable to national standards. The preferred transfer instrument, because of its long-term stability, is a well-type, sealed high-pressure ionization chamber. Alternative instruments such as gamma spectrometers or liquid scintillation counters may be employed but additional quality control measures may be necessary because of their susceptibility to short-term variations in response.
- 3.2 If the $4\pi\beta$ - γ coincidence technique is not applicable, for example for pure β -particle emitters, then calibration should be based upon some form of efficiency tracing method, or other method that can be successfully validated and verified.

4 SOLID SOURCES

- 4.1 Photon (γ - and X-ray) emitting sources should be calibrated by means of an ionisation chamber, or other suitable detector, that has itself been calibrated using standard sources of appropriate geometry. These standard sources shall either be prepared from previously standardised solutions, or subsequently standardised by dissolution and measurement in a manner traceable to national standards.
- 4.2 Solid sources prepared from standardised solutions should, in the absence of a more direct method of calibration, be provided with a calibration derived from the known mass or volume of solution dispensed.

5 RADIUM CONTENT: CALIBRATION OF ^{226}Ra SEALED SOURCES

- 5.1 Radium sources comprising encapsulated radium salt should be calibrated in terms of radium element content by comparison with suitable sources which have themselves been calibrated in a manner traceable to the 1934 international radium standards of Hönigschmid.

6 α -PARTICLE, β -PARTICLE or CONVERSION ELECTRON EMISSION RATE: CALIBRATION OF SOURCES

- 6.1 Small area sources with thick backings should be calibrated by $2\pi\alpha$ - or $2\pi\beta$ - counting, using a detector with a response determined in a manner traceable to national standards.
- 6.2 Large area α -particle or β -particle emitting sources should be calibrated by means of a large area proportional counter or other appropriate detector which has itself been calibrated using appropriate reference sources whose emission rate calibration is traceable to national standards.

7 X-RAY or g -RAY EMISSION RATE: CALIBRATION OF SOURCES

- 7.1 Solid or solution sources of well-defined geometry should be calibrated using a suitable detector that has itself been calibrated in a manner traceable to national standards.

8 NEUTRON EMISSION RATE: CALIBRATION OF SOURCES

- 8.1 The neutron emission rate from sealed radionuclide neutron sources should be determined by one of the following methods:
- (a) directly, using a manganese sulphate bath;
 - (b) indirectly, by comparison with an appropriate source whose emission rate has been determined with traceability to national standards.
- 8.2 Where the manganese bath technique is used to determine the absolute emission rate, the detectors shall be calibrated using ^{56}Mn that has been measured with traceability to national standards. The appropriate corrections must be applied for loss of neutrons by absorption by materials other than the manganese.
- 8.3 Indirect measurements of emission rate of a source should be made using a suitable moderator-detector arrangement with the source either placed inside the moderator or mounted externally to it.
- 8.4 Where necessary, due allowance should be made for any effect arising from anisotropy of neutron output.

9 AIR KERMA RATE: CALIBRATION OF SOURCES

9.1 The calibration of photon-emitting sources in terms of air kerma rate should use one of the following methods:

- (a) directly, by measurement of the source output (air kerma rate) in a known geometry using a calibrated instrument;
- (b) indirectly, by ionometric comparison of the source output with that of an appropriate standard source.

These methods are described more fully in paragraphs 9.2 - 9.4 [with the preferred methods being those in paragraphs 9.2 and 9.3(a)].

9.2 Direct measurements of source output should be carried out in an adequately defined source-detector geometry. An ionisation chamber of the appropriate sensitivity should be used and the energy dependence of the chamber response should be known over the range of photon energies to be measured. The calibration of this chamber should be traceable to national standards. Scattering from the surroundings should be kept to a practical minimum and appropriate corrections should be applied.

9.3 Indirect measurements of source output should be made by ionometric comparison with suitable sources that have been standardised in a manner traceable to national standards in terms of air kerma rate, or in terms of activity. The output of these standards sources in terms of air kerma rate shall be determined by one of the following accepted methods:

- (a) for sources standardised in terms of air kerma rate, by measurement of either of these quantities;
- (b) for sources standardised in terms of activity, by calculation using the air kerma rate constant for the radionuclide concerned, making appropriate allowance for attenuation of the emitted photons in both the source material and its encapsulation;
- (c) in the case of a radium standard source, by calculation from the radium element content determined in a manner traceable to international standards (see paragraph 5.1), using the exposure rate or air kerma rate constant appropriate to the design of the source concerned.

9.4 The ionometric comparison of sources for the indirect determination of source output should be carried out using an ionisation chamber of adequate sensitivity. Due allowance should be made for scattering and for the energy dependence of response of the chamber.

10 GENERAL

10.1 For any calibrated ionisation chamber or similar system providing the basis of a calibration facility, the constancy of the system response should be monitored at appropriate intervals by means of a suitable radionuclide check source.

10.2 Since activity, emission and exposure rates are stated in units which include the reciprocal of time, the laboratory should demonstrate the traceability of its time measurement to a suitable reference standard.