Essential Info When Dispensing Radioactive Material

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Radioactive Group

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Learning Objectives

- Describe National Institute of Standards and Technology primary and secondary sources.
- Discuss the differences required in chamber technology to measure energies.
- Explain the error rate in measuring activity from various radiopharmaceuticals.
- Describe how to change or add a new calibration setting on the capintec and Atomlab dose calibrators.

Disclosures

- Jeffrey T. Cessna declares no conflicts of interest, real or apparent, and no financial interests in any company, product, or service mentioned in this program, including grants, employment, gifts, stock holdings, and honoraria.

NIST Standards in Nuclear Medicine

Jeffrey T. Cessna
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You are measuring a source with a NIST-traceable activity of 20 MBq at time of measurement. What dial setting would you determine from the following data?

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- A: the dial setting is 020
- B: the dial setting is 074
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- D: the dial setting cannot be determined

Which of the following best describes metrological traceability?

- A: A documented chain of source custody from supplier to final measurement
- B: A full accounting of the process used to produce a weather forecast
- C: An unbroken chain of calibrations each with its own measurement uncertainty
- D: A full accounting of the legal requirements for measurement

Outline

- What is NIST?
- Development of Primary Standards
- Development of Secondary Standards
- Traceability
- Dissemination of Standards
- Uncertainties
- How to achieve traceability
- Current/Future Standards
- Changes in Standards
- Publications

Disclaimer

Certain commercial equipment, instruments, or materials are identified in this paper in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

What is NIST?

- An non-regulatory agency of the U. S. Department of Commerce, founded in 1901
- Responsible for developing, maintaining, and disseminating standards for all physical quantities in the U.S.
- About 5000 employees at two campuses
  - Gaithersburg, MD (~30 km from Washington, DC)
  - Boulder, CO (~30 km from Denver, CO)

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Primary method of measurement

“... is a method having the highest metrological qualities, whose operation can be completely described and understood, for which a complete uncertainty statement can be written down in terms of SI units, and whose results are, therefore, accepted without reference to a standard of the quantity being measured.”


Primary Standardization

“First time we see it.”

- Development of an accurate, reproducible method for assaying radionuclides
- For β, α emitting radionuclides, LS counting is preferred due to high detection efficiency
- Impurity analysis
- Uncertainty analysis as important as activity value

Primary Measurement Methods

- Each method has strengths/weaknesses
- Methods are complementary
- Perform standardization by as many methods as possible
- Uncertainties are well characterized
  - Typical uncertainties 0.5%

CNET uncertainties

Zimmerman and Coyle, JResNIST 102 (1997)
**International Comparisons**

- **Key Comparisons**
  - Consultative Committee on Ionizing Radiation (CCRI)
  - Mutual Recognition Arrangement (MRA)
  - Key Comparison Working Group

- **SIR – International Reference System**
  - Reference Chambers at International Bureau of Weights and Measures (BIPM)

- **SIRTI – Travelling Instrument**
  - Short-lived radionuclides

- **Bi-lateral comparisons**
  - NMI to NMI

Results are available at [http://kcdb.bipm.org](http://kcdb.bipm.org)

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**Comparison example: \(^{177}\text{Lu}\)**

- Laboratory identifier

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**Secondary Standards**

- Methods calibrated by primary methods
- Used to "store" those primary standards
- May include:
  - NIST secondary standard ionization chambers
  - Commercial radionuclide calibrators
  - Guidance on dial settings
  - Standard Reference Materials (SRMs)
- Complete understanding of different variables that affect measurement result
  - Effects of measurement geometry
- Provides a method to transfer the standard to the user

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**NIST dose calibrator studies**

- Determination of dial settings
- Investigation of possible sources of uncertainty or bias
  - Volume studies
  - Variability of containers
  - Depends on user requirements
  - Geometry may support manufacturing needs
  - Geometry may support clinical measurements
- NIST published dial settings are valid only for the NIST maintained calibrators at the time of measurement

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**Determination of dial settings**

- Dial-in method - activity is known at measurement time
- Calibration curve Method – activity is not known until after measurement time
Dial-in method

- Decay correct activity to time of measurement
- Change dose calibrator dial setting until...
- Known activity is shown on display
- Record dial setting

Calibration curve method

- Record instrument readout at a series of dials settings
- Use a range covering the expected source activity
- Determine source true activity
- Divide each instrument readout by true activity to give ratio (R)
- Plot R versus dial setting
- Fit an equation to the data
- Solve for R = 1.0
- Record dial setting

ICRM Life Sciences Working Group

The collection
- Excel spreadsheet
- Column headings
  - Radionuclide
  - Calibrator Manufacturer and Model
  - Container
  - Filling volume
  - Dial setting
  - Uncertainty on dial setting
  - Geometry correction factors
  - Notes
  - Reference
  - Document Object Identifier (DOI)
- Read Me
- Statistics

The collection

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dial Settings</td>
<td>396</td>
</tr>
<tr>
<td>Calibrator Models</td>
<td>11</td>
</tr>
<tr>
<td>Containers</td>
<td>33</td>
</tr>
<tr>
<td>NMIs</td>
<td>5</td>
</tr>
</tbody>
</table>

Contact jcessna@nist.gov

Traceability

2.41 (6.10) metrological traceability

property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

International Vocabulary of Metrology, JCGM 200 (2012)

NOTE 4 For measurements with more than one input quantity in the measurement model, each of the input quantity values should itself be metrologically traceable and the calibration hierarchy involved may form a branched structure or a network. The effort involved in establishing metrological traceability for each input quantity value should be commensurate with its relative contribution to the measurement result.

NOTE 5 Metrological traceability of a measurement result does not ensure that the measurement uncertainty is adequate for a given purpose or that there is an absence of mistakes.

Traceability to NIST: Official Policy

- Requires an unbroken chain of comparisons (with stated uncertainties) to stated reference
- Only measurement results are traceable – not procedures, instruments, etc.
- Provider of result is responsible for claims of traceability
- Assessing validity of claim of traceability is responsibility of user of reported value

http://www.nist.gov/traceability

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NIST Quality Assurance Program

- Covers all SRMs and Calibration Services
- Supports NIST claims of traceability
- Internal Assessment 2015
- External Assessment 2015 by SIM

Available at http://www.nist.gov/pml/div682/qualitysystem.cfm

Dissemination of Standards

- Standard Reference Materials (SRMs)
- Calibration Services
- Dial setting guidance
- Measurement Assurance Programs

With a properly controlled calibrator, shown to respond in the same way as a NIST dose calibrator, similar results can be expected.

NIST establishes Relationship

(calibration factor or correction factor)

Establishes link between dose calibrators

Clinic → Instrument Quality Control

Uncertainties

1 %

3 %

5-10 %

Sources

NIST (Primary standard)

Source Supplier (Secondary lab; Direct traceability)

Radiopharmacy (Direct or Secondary traceability)

Clinic (Secondary or No traceability)

NRMAP

- NIST Radiopharmaceutical Measurement Assurance Program
- Established in 1974
- Radionuclides chosen by participants
- 9 distributions of activity blinded SRMs
- 3 “Open” Months for submission of samples
- 14 Participants (2015)


Typical Distribution Schedule (2015)

<table>
<thead>
<tr>
<th>Month</th>
<th>Radionuclide</th>
<th>High Level</th>
<th>Low Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>^131I</td>
<td>750 MBq (20 mCi)</td>
<td>25 MBq (700 µCi)</td>
</tr>
<tr>
<td>February</td>
<td>^99Mo</td>
<td>3 GBq (80 mCi)</td>
<td>75 MBq (2 mCi)</td>
</tr>
<tr>
<td>March</td>
<td>OPEN</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>April</td>
<td>^67Ga</td>
<td>375 MBq (10 mCi)</td>
<td>20 MBq (500 µCi)</td>
</tr>
<tr>
<td>May</td>
<td>^99mTc</td>
<td>7.5 GBq (200 mCi)</td>
<td>n/a</td>
</tr>
<tr>
<td>June</td>
<td>OPEN</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>July</td>
<td>^111In</td>
<td>225 MBq (6 mCi)</td>
<td>35 MBq (900 µCi)</td>
</tr>
<tr>
<td>August</td>
<td>^125I</td>
<td>375 MBq (10 mCi)</td>
<td>20 MBq (500 µCi)</td>
</tr>
<tr>
<td>September</td>
<td>^131I</td>
<td>7.5 GBq (200 mCi)</td>
<td>750 MBq (20 mCi)</td>
</tr>
<tr>
<td>October</td>
<td>^90Y</td>
<td>75 MBq (2 mCi)</td>
<td>19 MBq (500 µCi)</td>
</tr>
<tr>
<td>November</td>
<td>OPEN</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>December</td>
<td>^131I</td>
<td>750 MBq (20 mCi)</td>
<td>6 MBq (150 µCi)</td>
</tr>
</tbody>
</table>

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Open months

- $^{22}$Na, $^{32}$P, $^{35}$S, $^{51}$Cr, $^{57}$Co, $^{67}$Ga, $^{68}$Ge/$^{68}$Ga, $^{75}$Se, $^{85}$Sr, $^{90}$Y, $^{90}$Y (glass microspheres), $^{90}$Sr, $^{99m}$Tc, $^{123}$I, $^{124}$I (capsules), $^{125}$I, $^{131}$I, $^{131}$I (capsules), $^{133}$Ba, $^{137}$Cs, $^{153}$Gd, $^{153}$Sm, $^{166}$Ho, $^{177}$Lu, $^{201}$Tl, and $^{223}$Ra

NRMAP Results

A grain of salt…

- Measurements must be considered in context
  - Need to conform to study protocols
  - Dosage may be determined from trial data that is not traceable to national standard
  - Clinical measurements should always be done in accord with the manufacturers instructions
- Required measurements are based on needs
  - Volume studies not required for fixed dose

Current NIST Standards

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>$T_{1/2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{18}$F</td>
<td>109.7 m</td>
</tr>
<tr>
<td>$^{62}$Cu</td>
<td>9.67 m</td>
</tr>
<tr>
<td>$^{68}$Ge</td>
<td>270.95 d</td>
</tr>
<tr>
<td>$^{88}$Y</td>
<td>106.6 d</td>
</tr>
<tr>
<td>$^{111}$Pd</td>
<td>16.99 d</td>
</tr>
<tr>
<td>$^{111}$In</td>
<td>14.00 d</td>
</tr>
<tr>
<td>$^{113}$In</td>
<td>1.117 d</td>
</tr>
<tr>
<td>$^{125}$I</td>
<td>6.65 d</td>
</tr>
<tr>
<td>$^{119}$Sn</td>
<td>3.777 d</td>
</tr>
<tr>
<td>$^{119}$Cs</td>
<td>15.94 h</td>
</tr>
<tr>
<td>$^{186}$W/$^{188}$Re</td>
<td>69.4 d</td>
</tr>
<tr>
<td>$^{188}$Re</td>
<td>138.38 d</td>
</tr>
</tbody>
</table>

New/in progress NIST Standards

- Therapy: $\alpha$-emitters
  - $^{223}$Ra (completed 2008/2010)
  - $^{212}$Po
  - $^{212}$At
  - $^{212}$Ac
- Imaging: PET
  - $^{68}$Ge/$^{68}$Ga (completed 2007)
  - $^{68}$Ga
  - $^{68}$Ge
  - $^{82}$Sr/$^{82}$Rb
  - $^{64}$Cu (in progress 2015)

Changes to Standards

- Fluorine-18
  - To resolve discrepancy in key comparison
- Radium-223
  - To resolve discrepancy with fellow NMI

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Fluorine-18

• Dial settings have changed

Radium-223

• Dial settings have changed

Publication of Results

• Applied Radiation and Isotopes
• Journal of Research of NIST
• The Journal of Nuclear Medicine
• Others
  • Medical Physics
  • Nuclear Medicine and Biology
  • Journal of Nuclear Medicine Technology

Key Points

• NIST provides a framework for traceability through:
  – Establishing primary standard
  – Developing secondary standards
  – Disseminating those standards
• It is important to understand the context of the measurements you are making
  – Traceability to NIST is the ideal, but not always utilized
  – Follow manufacturers instructions when necessary
  – Question when traceability is unclear

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Dose Calibrators

Mary Anne Yusko
Capintec, Inc.
March 6, 2016

Disclosures

Mary Anne Yusko is employed by Capintec, Inc.

General Discussion Points are Applicable to All Dose Calibrators Used for Radiopharmaceuticals

Data and Specifications Used as Examples are Specific to Capintec Dose Calibrators

The American Pharmacists Association is accredited by the Accreditation Council for Pharmacy Education as a provider of continuing pharmacy education.

Which of the following is the best process to improve accuracy when dispensing a unit dose in a syringe for new pure beta emitter?

• A: Assume that no volumetric corrections are needed.
• B: Use correction factors developed for Tc-99m.
• C: Apply correction factors developed for another beta pure emitter.
• D: Perform volumetric geometry test for each container type of interest (syringe and/or vial) with the new isotope.

Which of the following are possible sources of measurement error?

• A: Mix sample holders and/or moly assay canisters and calibrator from different manufacturers.
• B: Use standard length sample holders or liners for calibrators flush mounted in a hot cell or hood.
• C: Assume background rate remains constant in a hot lab when measuring low activity samples.
• D: All of the above.
**System Components**

- Sealed, pressurized, inert gas-filled re-entrant well chamber
- High voltage supply
- Electronics which amplifies and quantifies the signal (fA to µA)
- Algorithm to convert current to activity
- User controller/Interface

**Principle of Operation**

- Radiation ionizes fill gas
- Applied voltage differential creates current
- For a given isotope in a given configuration, current is directly proportional to amount of activity

**Uses**

- Measures gamma and x-ray emissions
- Measures high energy betas (> 800 keV) (Bremsstrahlung)
- Medical, research, industrial applications
- Wide dynamic measurement range (8 decades)
- Wide variety of sample configurations
- Minimum energy limited by inner wall thickness
- Sensitivity limited by pressure of fill gas
- Not suitable for low energy betas (¹⁴C, ³H) or pure alpha emitters with no gamma emissions
- Does not provide energy identification

**Design Criteria**

- Re-entrant well dimensions: minimize geometric affects
- Type and pressure of gas: sensitivity and measurement range
- Voltage Range (achieve saturation for all photon energies and maximum activities)
- Chamber shielding effects
- User interface requirements

**Chamber Design**

Physical Dimensions Affect Response
- Custom extruded 1100 alloy high purity aluminum - required for welding high pressure vessels (180 psi)
- Wall thickness 0.104" (2.64 mm)
- Internal Depth 10.25" (26 cm)
- Internal Diameter 2.75" (7 cm)
**Vertical Geometry**

- Capintec chamber wall thickness 0.104” energy cut off 13 keV, attenuation at 25 keV is approximately < 50%, maximum energy 3 MeV
- Deep well provides a vertical geometric independence

**Volumetric Geometry**

- 3 cc Syringe Tc-99m
  - 0.5  | 5.02 | 1.00
  - 1.0  | 5.02 | 1.00
  - 1.5  | 4.94 | 1.01
  - 2.0  | 4.92 | 1.02
- 5 cc Syringe
  - 0.5  | 2.14 | 1.00
  - 1.0  | 2.13 | 1.00
  - 1.5  | 2.13 | 1.00
  - 2.0  | 2.13 | 1.00
  - 2.5  | 2.12 | 1.01
  - 3.0  | 2.12 | 1.01
  - 3.5  | 2.12 | 1.01
  - 4.0  | 2.12 | 1.01

**Volumetric Geometry**

- 20 cc Vial Tc-99m
  - 1  | 5.94 | 1.00
  - 2  | 5.93 | 1.00
  - 3  | 5.92 | 1.00
  - 4  | 5.94 | 1.00
  - 6  | 5.95 | 1.00
  - 8  | 5.96 | 1.00
  - 10  | 5.96 | 1.00
  - 12  | 5.97 | 0.99
  - 14  | 5.96 | 1.00
  - 16  | 5.97 | 0.99
  - 18  | 5.96 | 1.00
  - 20  | 5.98 | 0.99

**Design Criteria**

- Type and Pressure of Gas
  - First Ionization Potential (eV)
  - W-Value (mean eV/ ion pair)
  - Argon 15.7 26.2
  - Nitrogen 14.2 34.6
  - Xenon 12.1 21.9
- Research Grade Argon; 99.99%

**Sensitivity and Measurement Range**

- Capintec Chambers Tc-99m
  - F-18 Resolution
  - R chamber 12 atm 6 Ci 3 Ci 0.01µCi
  - PET chamber 5 atm 74 Ci 20 Ci 0.1 µCi
  - 77T chamber 1 atm 400 Ci 150 Ci 10 µCi

**Chamber Housing**

- Physical support for detector, radiation shielding
- Reduces background effects on measurement
- Reduces radiation exposure to personnel
- 1/8” (3.2 mm) integral lead shielding
- 0.81” (21 mm) air gap between chamber and lead shield reduces backscattering effect (most prominent between 70 keV and 250 keV)
- Can add external shielding without impacting measurements
**User Interface**

Hardware: keypad, touch screen, PC, web based, network ready, PoE

Software: converts current to activity, automated QC, inventory, calculations, presets, reports, labels and tickets, PC communication, network interface, management system compatibility

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**QC All Calibrator Models**

- Zero Adjustment (nulls electronics)
- Background Adjustment (offsets ambient room radiation)
  Should be measured frequently if background changes often
- Contamination Check of Liner or Dipper
- A dedicated check source of known activity to monitor sensitivity, electronic drift, reproducibility and calibration over long term life of the instrument

---

**Yesterday’s QC**

- Based on analog systems - electromechanical switching mechanisms
- Daily constancy - switches could wear independently
- Daily check of battery voltage
- Quarterly linearity – non-linearity at point of range change
  - loss of DC battery voltage recombination effect
- Annual accuracy with multiple sources - mechanical calibration pots

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**Today’s QC**

Based on microprocessor/digital circuitry

Daily-Automated QC

- Voltage adjust (No Battery) AC to DC converter, DC to DC step up converter for desired voltage
- Data check-confirm integrity of programs and stored data
- Calibration curve or look up table stored in software

---

**Today’s QC**

Digital Circuitry and User Interface

- Eliminate constancy: of no value using keypad, touch screen or PC technology
- Linearity annually: over range of clinical interest
- Geometry: acceptance testing only - isotope specific

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**Calibration Process**

Develop a sensitivity curve of chamber response as a function of photon energy

- Manually calculate using available standards and copper attenuators to simulate single photon emissions
- Develop a calibration look up table
- Monte Carlo simulations
- Confirm by participation in NRMAP
- Incorporate a standardization process
- Develop geometric corrections for various container types or volumes if difference is significant
Calibration Process

• Reference samples- geometry NIST SRM flame sealed glass ampoule 5 ml in HCl carrier solution 0.6 mm wall thickness
• Capintec sets two points of curve with $^{57}$Co and $^{60}$Co, to adjust sensitivity and slope of each chamber’s response as close as possible to the default curve
• 2012 Capintec re-affirmed common radiopharmaceuticals by participation in NIST Radioactivity Measurement Assurance Program (NRMAP)
• 2013 developed Monte Carlo simulation of chamber using ORNL MCNP code. We can now run alternative geometries and alternative fill pressures

Calibration Process

• Early chambers (1970s) had a greater variability in aluminum then today’s custom extruded aluminum
• Early reference standards had greater variability
• Three data sets agreed remarkable well-testament to long term effort at controlled manufacturing uniformity (1970s to 2013s)
• Collected NRMAP data from other participants, calibrators on permanent loan at NIST
• Published calibration numbers +/- 5% compared to current standards
• Current process works well and provides a system which is within the accuracy range for diagnostic doses

Desire for improved accuracy for certain applications

• Volumetric PET and volumetric SPECT applications
• Therapeutic radiopharmaceuticals -alpha emitters, distribution pharmacies and end user customers should receive NIST traceable reference dose in distribution container to individually adjust calibration numbers
• Brachytherapy calibration-regional ADCL or NIST traceable source from manufacturer to individually adjust calibration numbers
• Capintec can improve accuracy of measurements with minor adjustments to calibration numbers for selected isotopes
• Expect to publish a revised calibration data set for a few select isotopes which are between 4-5% in 2016

Measurement Concerns

• Geometric variation from reference container (NIST SRM)
• Alternative geometries (capsules, seeds, spheres, wires, etc.) require different calibration numbers or correction factors
• Capintec refers users to manufacturer for NIST traceable reference sample or recommended calibration number
• Capintec recommends customers obtain a NIST traceable reference sample from manufacturer or radiopharmacy in distribution vial for therapy products to improve accuracy ($^{223}$Ra)
• Changes in reference standard (NIST $^{18}$F, $^{223}$Ra, $^{133}$Ba)

Measurement Concerns

• Linearity: $^{99}$Mo can cause non-linear affect on a large $^{99m}$Tc source
• Residual activity in needle or syringe: low volume high activity
• Retention of activity plated onto the syringe
• Radionuclide impurities, ingrowth or non-equilibrium state
• Attenuation of carrier solution for low energy isotopes
• Do not use the calibrator for waste storage-e.g.PET
Measurement Concerns

- Comply with warm up period, avoid vibration
- Monitor changes to ambient background rate when background may change significantly (hot cell environment)
- Measure low activities - e.g. $^{82}$Sr breakthrough for $^{82}$Rb generator - take 10 readings and average
- High Energy Beta emitters ($^{89}$Sr, $^{90}$Y, $^{32}$P) require multipliers due to low sensitivity of bremsstrahlung - background may affect readings
- Batch variation from manufacturer in container or concentration
- Countersunk modification - extended liner and sample holder

New Applications

On-going research in therapeutic alpha emitters (IAEA)

<table>
<thead>
<tr>
<th>$^T$1/2</th>
<th>$\alpha$ (MeV)</th>
<th>$\gamma$ E (keV)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{211}$At</td>
<td>7.2 h</td>
<td>5.869</td>
<td>41.8</td>
</tr>
<tr>
<td>$^{212}$Bi</td>
<td>60.55 m</td>
<td>6.05</td>
<td>25.1</td>
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<tr>
<td>$^{213}$Bi</td>
<td>45.59 m</td>
<td>5.575</td>
<td>1.96</td>
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<tr>
<td>$^{223}$Ra</td>
<td>9.92 d</td>
<td>5.830</td>
<td>50.7</td>
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<tr>
<td>$^{212}$Pb</td>
<td>10.2 m</td>
<td>6.050</td>
<td>25.13</td>
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<tr>
<td>$^{227}$Th</td>
<td>18.68 d</td>
<td>6.038</td>
<td>24.2</td>
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<tr>
<td>$^{148}$Tb</td>
<td>4.12 h</td>
<td>3.967</td>
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</table>

New Applications

On-going research in medical radiometals (MURR)

<table>
<thead>
<tr>
<th>$^T$1/2</th>
<th>$\beta$ Max (MeV)</th>
<th>$\gamma$ E (keV)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{47}$Sc</td>
<td>3.349 d</td>
<td>0.600</td>
<td>159.4</td>
</tr>
<tr>
<td>$^{64}$Cu</td>
<td>12.7 h</td>
<td>0.653 (19%)</td>
<td>511</td>
</tr>
<tr>
<td>$^{67}$Cu</td>
<td>2.58 d</td>
<td>0.577</td>
<td>184.6</td>
</tr>
<tr>
<td>$^{71}$As</td>
<td>2.72 d</td>
<td>0.81</td>
<td>175</td>
</tr>
<tr>
<td>$^{72}$As</td>
<td>26.0 h</td>
<td>3.34</td>
<td>834</td>
</tr>
<tr>
<td>$^{77}$As</td>
<td>38.8 h</td>
<td>0.68</td>
<td>239</td>
</tr>
<tr>
<td>$^{212}$Pb</td>
<td>10.64 h</td>
<td>0.574</td>
<td>238.6</td>
</tr>
<tr>
<td>$^{117}$InSn</td>
<td>13.6 d</td>
<td>0.13 - 0.16</td>
<td>156</td>
</tr>
<tr>
<td>$^{67}$Ga</td>
<td>3.26 d</td>
<td></td>
<td>184.6</td>
</tr>
<tr>
<td>$^{111}$In</td>
<td>2.8 d</td>
<td></td>
<td>173</td>
</tr>
</tbody>
</table>

New User Requirements

- Desire for improved accuracy (volumetric and therapeutic)
- Record of residual activity after administration (therapy)
- New and unique geometries - 188Re paste for skin cancer
- Increased radiopharmaceutical use in Veterinary and pharmaceutical research
- Ongoing demands for improved Interface speed and connectivity - networks, management systems, gamma camera
- Publish or post manufacturer’s derived cal # for alternative geometries (e.g. iodine capsules, spheres)

New User Requirements APhA - Tell us your needs!
Which of the following is the best process to improve accuracy when dispensing a unit dose in a syringe for new pure beta emitter?

• A: No volumetric corrections are needed.
• B: If no correction factors are required for Tc-99m, then no corrections are required for any isotope.
• C: Apply correction factors developed for another beta pure emitter.
• D: Perform volumetric and container geometry tests for each container type of interest (syringe and/or vial) with the new isotope.

Which of the following are possible sources of measurement error?

• A: Mix the sample holders and/or moly assay canisters and calibrator from different manufacturers.
• B: Use standard length sample holders or liners for calibrators flush mounted in a hot cell or hood.
• C: Assume background rate remains constant when measuring low activity samples.
• D: All of the above.

Questions:
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Always Best to End with a Smile!