Dose calibrator quality control

Hind Saikouk[1,2]

[1]:Faculty of science of Rabat, Mohammed V University, Morocco

[2]: Medical physicist, Nuclear medicine department, Hematology and oncology hospital, Mohammed VI University Hospital, Marrakesh

Email: saik.hind@gmail.com

Nuclear medicine

- Nuclear medicine is a medical specialty where radiopharmaceuticals are used for diagnosis or treatment
  - Radiopharmaceutical: radionuclide bonded to a "carrier" molecule
    - Example: Tc99m-HMDP, Tc99m-MIBI, F18-FDG, I131
  - Diagnosis: X, gamma and $\beta+$ emitters (annihilation photons)
  - Therapy: metabolic radiotherapy: $\beta-$ and α emitters

Nuclear medicine procedure

Waiting time:
minutes-hours

Diagnostics

Therapy

Radiopharmaceutical preparation/Dose fractionation

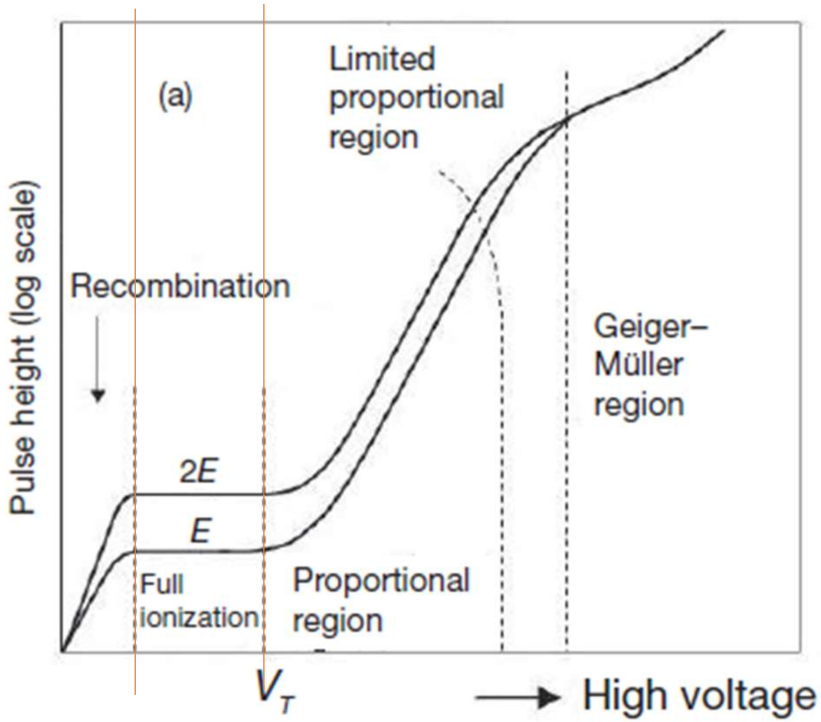
Activity measurement

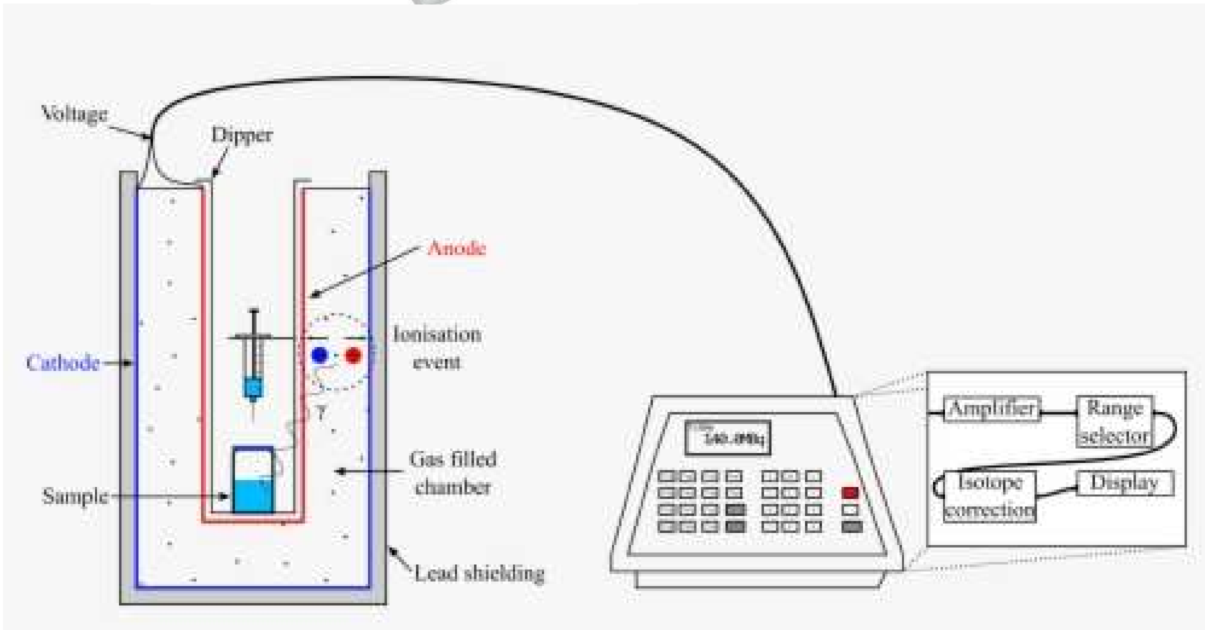
Administration of the radiopharmaceutical

- Patient's Hospitalization
- Release of the patient

Dose calibrator

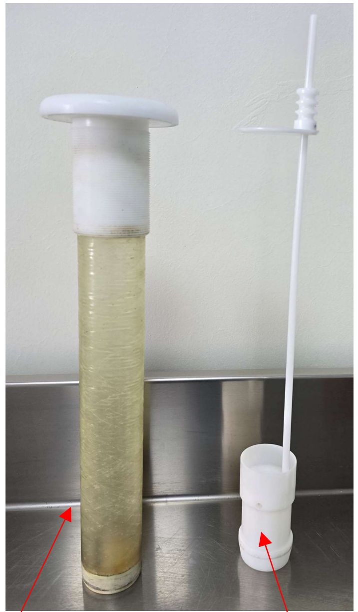
- Gaz filled detector: Ionization chamber





Ionizing chamber **Control and display unit**

Dose calibrator



Dose calibrator
internal walls
(can be removable)

Dose calibrator
dipper

General characteristics

- Filling gas is pure Argon under pressure (typically 1-2 MPa)
- Chamber constructed in Aluminum
- The chamber is shielded with Lead, typically 3 - 10 mm, to reduce interference from external radiation
- Measurement of activity in samples radiopharmaceuticals: one sample per measurement
- High detection efficiency for X and gamma,
- Low detection efficiency to β particles: response from bremsstrahlung radiation
- Activity range: up to 100 GBq
- Short time for stable response: 2- 10 seconds
- Activity may vary depending on the position and the shape of the sample: Correction factors
- Biasing voltage: depends on the manufacturer (160 V for Lemerpax, 150 V for Capintec, 450 V for Atomlab)

Dose calibrator: quality controls

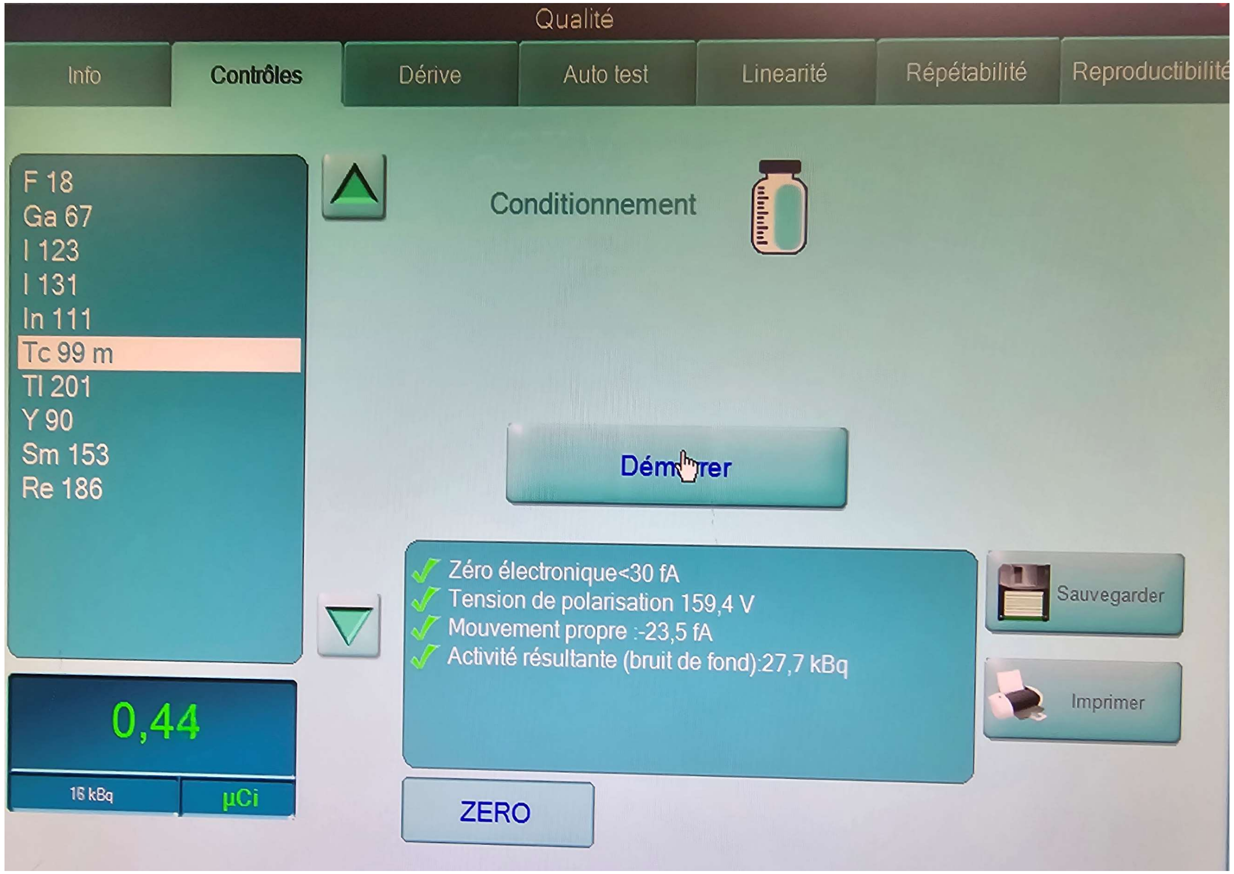
- Routine quality controls: Zero adjustment, background, biasing voltage
- Daily: Constancy
- Annual: Repeatability, accuracy, reproducibility, linearity

Daily QC

Routine QC

- Zero Adjustment
  - Response of the electrometer when the output of the ionizing chamber is short-circuited
    - No source is inside the ionizing chamber
    - No contamination is detected
  - The value should not exceed 3,7 MBq
- Biasing voltage
  - Verification of the value of the voltage applied on the ionizing chamber
  - Avoid falling on the recombination region
  - Should not exceed ±10% of the constructor value
- Background
  - Even if the source holder is empty, the dose calibrator will still record an ‘activity’ due to background radiation
  - The current value in the absence of any radioactive source
    - No source is inside the ionizing chamber
    - No contamination is detected
  - Should not exceed 100 fA
  - An increase of 20% above the limit should call for further investigation

Routine QC



Qualité
Info
Contrôles
Dérive
Auto test
Linearité
Répétabilité
Reproductibilité
F 18
Ga 67
I 123
I 131
In 111
Tc 99 m
Tl 201
Y 90
Sm 153
Re 186
Conditionnement
Démarrer
Zéro électronique<30 fA
Tension de polarisation 159,4 V
Mouvement propre :-23,5 fA
Activité résultante (bruit de fond):27,7 kBq
Sauvegarder
Imprimer
0,44
16 kBq
µCi
ZERO

Constancy

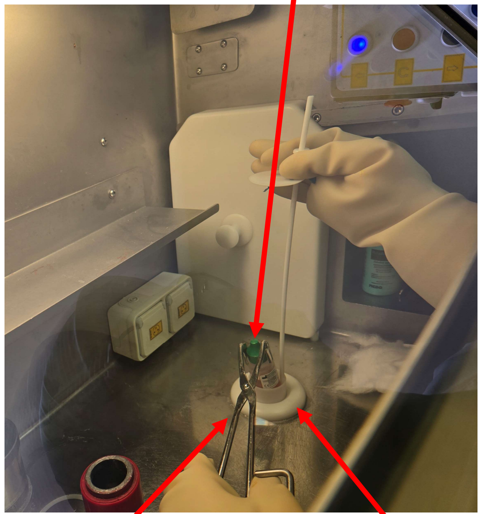
- Measurement of the capacity of the radionuclide activity meter to give reproducible response on day-to-day basis with good precision
- Protocol:
  - Use of long lived reference source (constancy sources: Co57, Cs 137, Ba 133)
  - Put the source inside the ionizing chamber well using tongs
  - Measure the activity of the source with the desired radionuclide setting (ex: Tc99m)
  - Compare the measured activity to the calculated activity (corrected for the radioactive decay)
  - The **percent deviation** should not exceed **5%**

Constancy

Radionuclide	Half-life	Energy	Activity of reference	Date of reference
Co57	271,79 days	122 keV (85%)	204 MBq	01/05/2014 at 12h
Cs 137	30,17 years	662 keV (85%)	6,967 MBq	01/05/2014 at 12h
Ba133	10,574 years	356 keV (62%)	8,569 MBq	01/05/2014 at 12h

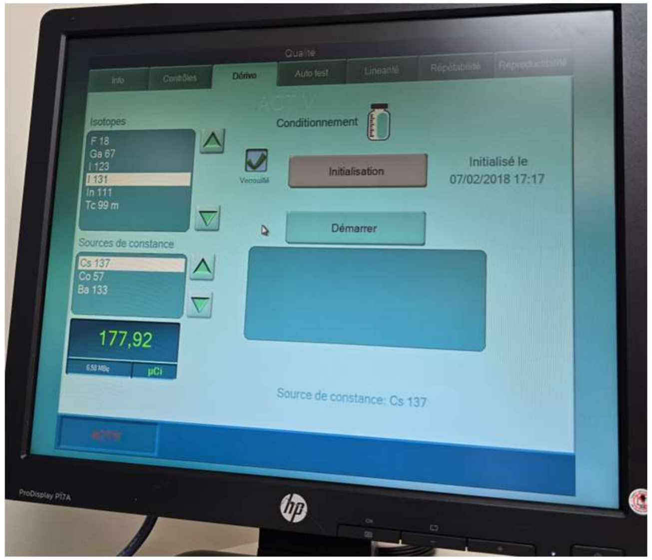
Constancy

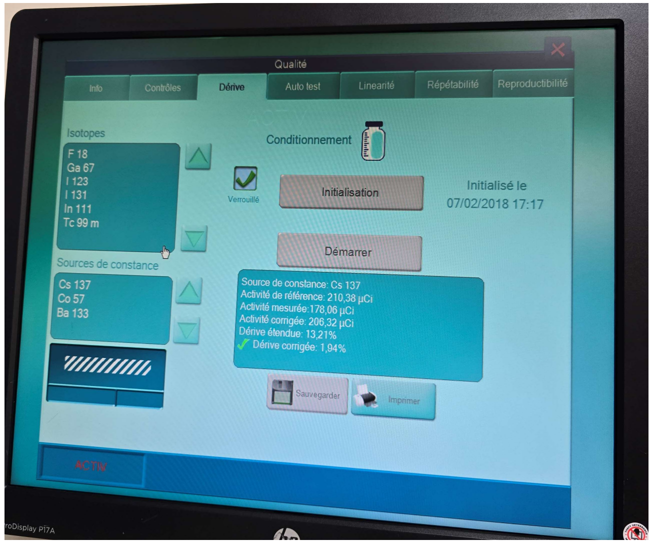
Cs 137
sealed source



Manipulation tongs

Ionization chamber well





Annual QC

Reproducibility

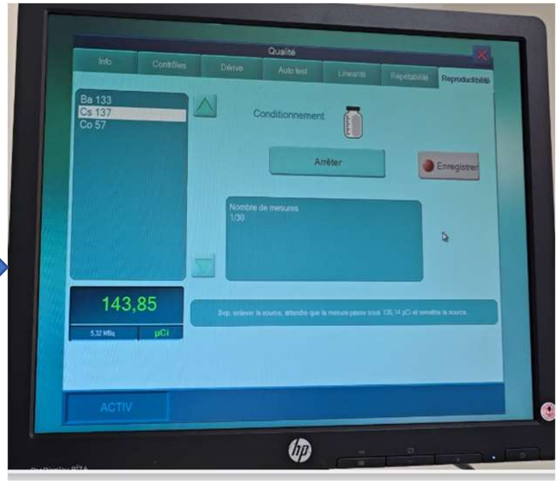
- Measurement of the instrument precision and verification that reproducible readings are obtained when some measurement conditions are changed:
  - Taking repeated measurements of the same source
  - The source is removed between measurements
  - 30 activities are recorded
  - Calculate the mean and the standard deviation of the obtained values
  - **Relative standard deviation (RSD)** should not exceed 1 %

$$RSD = \frac{\frac{\sqrt{\sum_{i=1}^{n}(A_i - \bar{A})^2}}{n-1}}{\bar{A}}$$

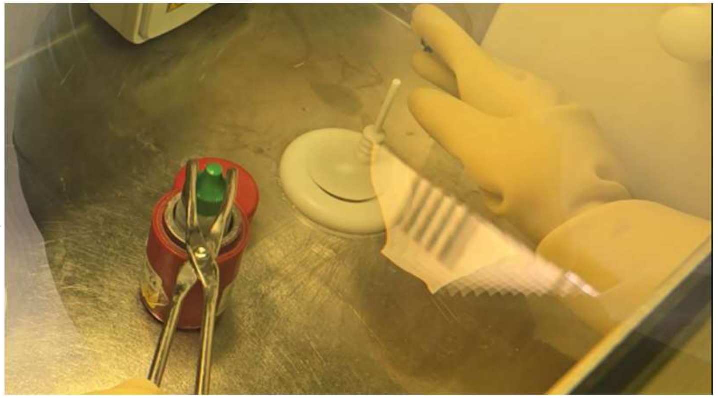
Where: A_i is the individual measured activity
$\bar{A}$ is the mean activity
n is the number of measurements

Reproducibility

Insert the Cs 137 source



Measure the activity



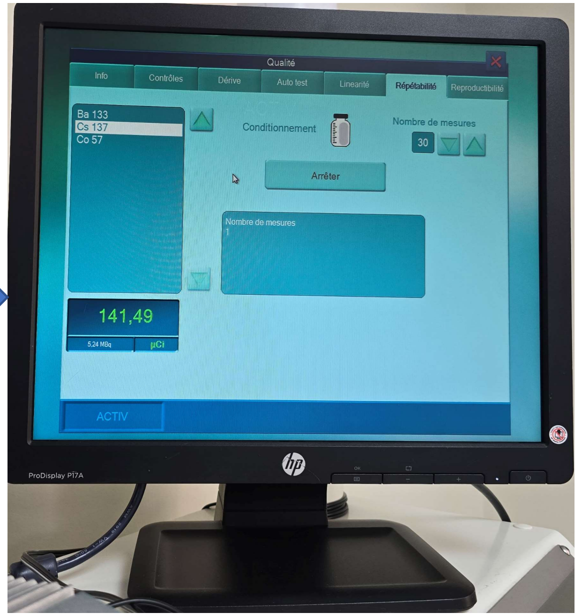
Remove the source from the well

Re-insert the source and repeat the same procedure for 30 times

Accuracy and repeatability

- Measurement of the instrument accuracy and precision under the same measurement conditions:
  - Place the source (ex: Cs137) inside the ionizing chamber well using the tongs and the dipper
  - Take 30 successive measurement
  - **Repeatability**: Calculate the mean and the relative standard deviation of the obtained values
    - **Relative standard deviation** should not exceed 0,2%
  - **Accuracy**: the **mean measured activity** should not exceed ± 10% of the **calculated activity** (corrected for the radioactive decay)

Accuracy and repeatability

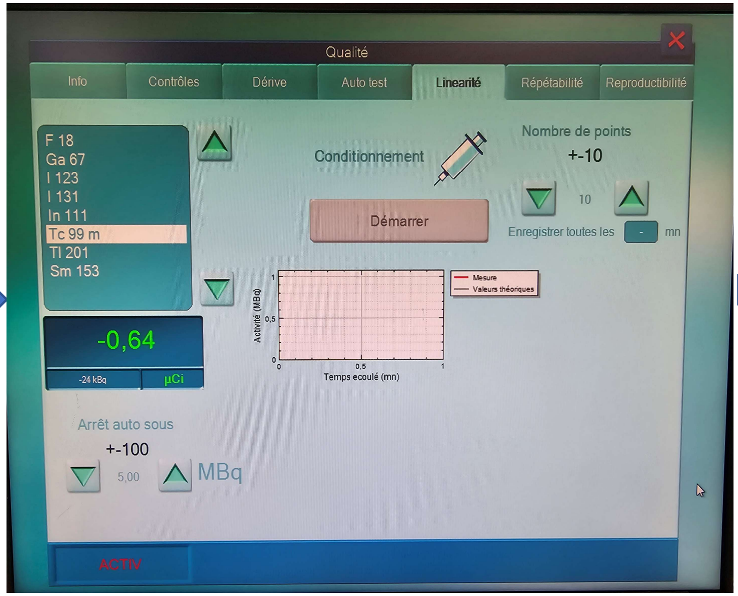


Repeat measurement for 30 times with the source inside the dose calibrator well

Linearity

- The capacity of the radionuclide activity meter to provide a linear response over the range of activities to be used
- Use a short-lived radioactive source (ex: Tc99m) with the maximum activity used for patients (5,5 GBq)
- Note down the initial activity and time
- Repeat measurements every 2-3 hours for a period greater than the radionuclide half-life
- Stop the measurement when the activity reach 1 MBq
- The percent deviation should not exceed 5 %
- Plot the decay curve, extract the measured half-life
- Plot the decay curve over a logarithmic scale
- Inspect the linearity over the ranges of activities

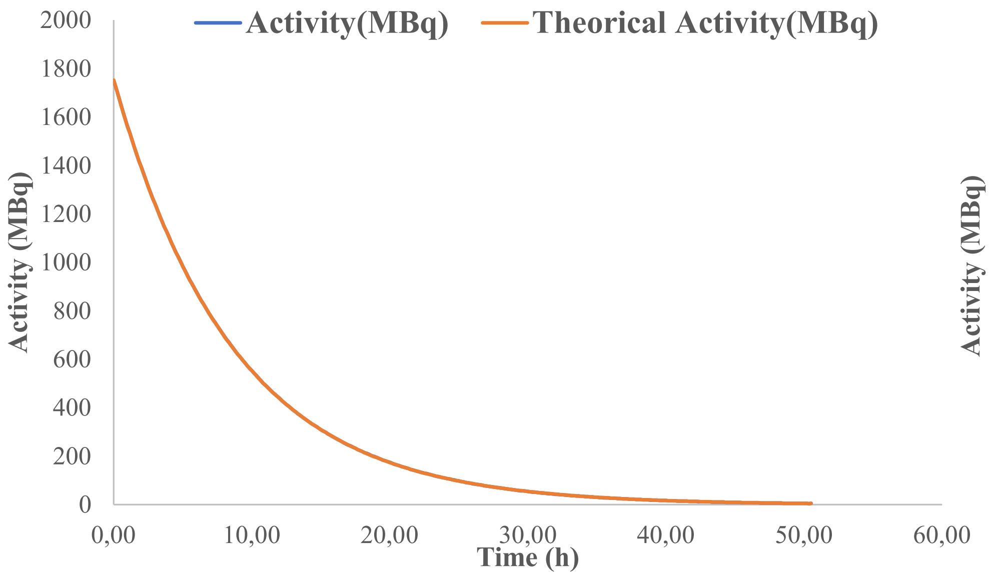
Linearity

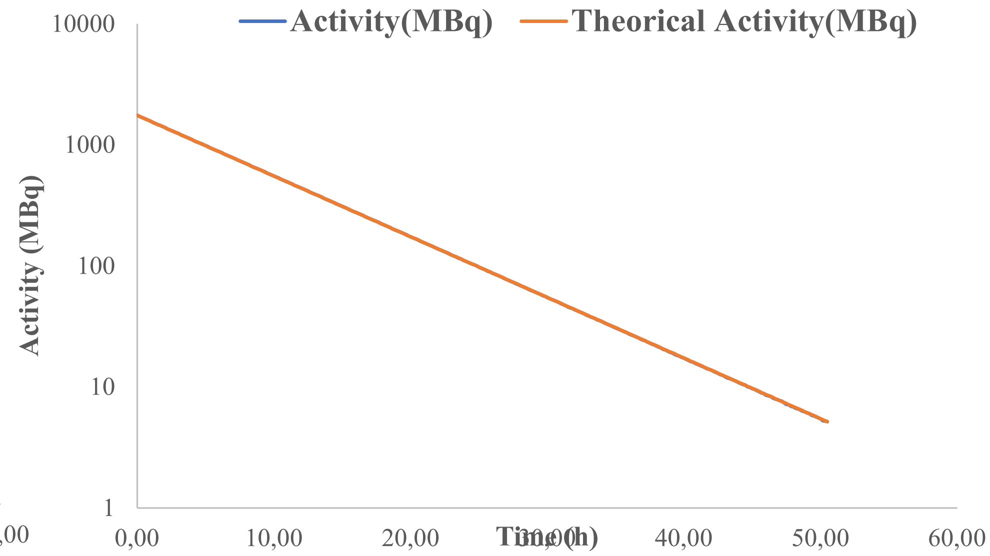


Repeat measurement every 2-3hours until the activity reach 1 MBq

Put the source inside the dose calibrator well

Linearity


Activity(MBq)
Theorical Activity(MBq)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Activity (MBq)
0,00
10,00
20,00
30,00
40,00
50,00
60,00
Time (h)


Activity(MBq)
Theorical Activity(MBq)
10000
1000
100
10
1
Activity (MBq)
0,00
10,00
20,00
30,00
40,00
50,00
60,00
Time (h)

Exercices

Constancy

Radionuclide	Corrected activity (MBq)	Measured activity (MBq)	Percent deviation (%)	Observation	Reference date
I 131	7.88	7,87			08-02-2018
Ga 67	24.46	24.43			08-02-2018

Reproducibility

Radionuclide	Mean measured activity (MBq)	Standard deviation	Relative standard deviation
Cs137			

Measurement number	Activity (MBq)
1	6,234722
2	6,25317849
3	6,16243738
4	6,26879877
5	6,27718934
6	6,15600639
7	6,24147112
8	6,17379196
9	6,1979407
10	6,23802236
11	6,23924126
12	6,23866306
13	6,22472391
14	6,23304753
15	6,20668997

16	6,18819224
17	6,26073004
18	6,27576753
19	6,1683923
20	6,18988478
21	6,22705656
22	6,24120439
23	6,20420226
24	6,22455433
25	6,16590584
26	6,28767824
27	6,22503701
28	6,25237324
29	6,22989113
30	6,20708422
31	6,24897306

Accuracy and repeatability

- Cs137 constancy source was used for the repeatability and accuracy quality controls. The source reference activity and date are: 6,9671 MBq, May 1st, 2014.
  - Calculate the accuracy and determine the repeatability

Measurement number	Activity (MBq)
1	6,72033313
2	6,75166108
3	6,71525389
4	6,71667389
5	6,72359055
6	6,71434688
7	6,71723403
8	6,70001667
9	6,71056049
10	6,70092719
11	6,70860886
12	6,70444695
13	6,70829156
14	6,72145582
15	6,69003269
16	6,72760752
17	6,70368079
18	6,7158435
19	6,69912645
20	6,71589348
21	6,73286001
22	6,7086886
23	6,72727678
24	6,71992024
25	6,72121036
26	6,71955771
27	6,71054685
28	6,69964672
29	6,71730475
30	6,72366005

Accuracy and repeatability

Accuracy

Radionuclide	Calculated activity	Mean measured activity (MBq)	Difference
I 131			

Repeatability

Radionuclide	Mean measured activity (MBq)	Standard deviation	Relative standard deviation
I 131			

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Comité de rédaction

• CEA/Laboratoire National Henri Becquerel

Laboratoire National Henri Becquerel

Philippe BLANCHIS, coordinateur
Marie-Noëlle AMIOT
Muriel MOUNE

• Société française de physique médicale

sfpm

Isabelle GARDIN
Antoine MARTINEAU
Marcel RICARD

• Société française de radiopharmacie

Sophie BONNOT-LOURS
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