Measurement of Tritium, gross α/β and ^{222}Rn using the Quantulus GCT 6220

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Introduction

Overview:

- Used Instrumentation
  - Quantulus GCT 6220
  - Guard Compensation Technology (GCT)
- European directive 2013/51 Euratom
- Experimental part
  - ^{3}H measurements
  - ^{222}Rn measurements
  - Gross α/β measurements

Quantulus GCT 6220

Patent pending Guard Compensation Technology

Resulting in lowest backgrounds

Quantulus GCT 6220

The Quantulus GCT is using a Tri-Carb housing but inside it is different. The new Quantulus uses the α/β–discrimination of the Quantulus 1220, pulse amplitude comparison of the Quantulus 1220, new Pulse Shape Analysis (using Histrogram mode) and the new GCT technology for background reduction.

The Quantulus GCT is still based on the BGO-guard detector. The patent pending GCT technology eliminates background which was overseen by the Guard in the past.

Resulting in lower background with still high efficiency and consequently higher sensitivity compared to older models.

Principle of the Guard Compensation Technology

An external γ–source close to the instrument is used to determine the efficiency of the BGO guard. Counts in coincidence with the guard are stored in one MCA and signals not in coincidence with the guard but detected in the sample chamber are stored in a second MCA.

The guard efficiency is defined as follows:

$$GE_R = \frac{SP12_R}{SP12_R + SP11_R}$$

Once knowing the Guard Efficiency compensated guard counts can be determined.

Principle of the Guard Compensation Technology

Subtracting the number of counts coincident with the guard from the compensated guard counts results in the counts missed by the guard detector.

$$GCM_R = CGC_R - SP12_R$$

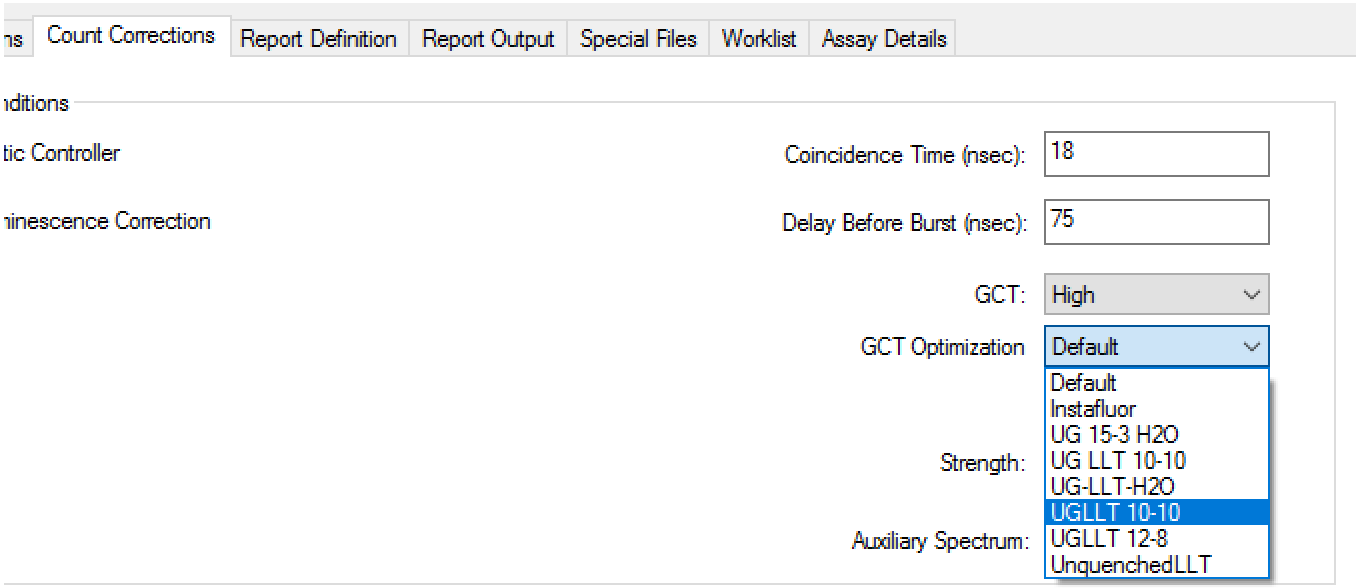
The number of missed guard counts are used to correct the background.

The guard compensation (efficiency) is energy dependent conseqeuntly long counting times are required for the efficiency determination.

More than one efficiency table might be necessary for different situations such as glass or plastic vials.

Principle of the Guard Compensation Technology

The QuantaSmart software allows to choose from a library of GCT optimization files for correct background compensation for different applications.



European Council Directive 2013/51 Euratom

What does the Council Directive cover?

Water intended for human consumption. All water intended for drinking, cooking, food preparation or other domestic purposes supplied in distribution network, a tanker, or in bottles or containers.

Indicative Dose 0.1 mSv, effective dose of all ingested radionuclides in one year via consumption of water intended for human use excluding ^{3}H, ^{40}K, Rn and short lived decay products.

The European Council set parametric values and required detection limits for the used instrumentation for nuclides of interest.

European Council Directive 2013/51 Euratom

Nuclide	Parametric Value (Bq/l)	Required Detection Limit (Bq/l)
^{3}H	100	10
^{222}Rn	100	10
Gross α	0.1	0.04
Gross β	1.0	0.40

The measurement of above nuclides attracted a lot of interest among the LSC community because of the simplicity of the measurement for drinking water and the high number of samples.

^3H Measurements in water

Sample preparation:

All water samples were distilled before counting.

All samples contained 8 ml of water and 12 ml of Ultima Gold LLT in plastic vials.

All measurements have been done in the PerkinElmer office in Hamburg using the optimized window determined with the SpectraWorks2 software. Counting window from 0.5 – 4.0 keV.

^3H Measurements in water

Instrument	Efficiency (%)	BG (CPM)	Count Mode	E^2/B
Tri-Carb 4910	25.7	1.91	● NCM	346

● Normal Count Mode ● Low Level Count Mode ● Super Low Level Count Mode ● NCM with GCT off

● NCM with GCT High

^3H Measurements in water

Instrument	Efficiency (%)	BG (CPM)	Count Mode	E^2/B
Tri-Carb 4910	25.7	1.91	● NCM	346
Tri-Carb 4910	23.0	1.29	● LLCM	410

● Normal Count Mode ● Low Level Count Mode ● Super Low Level Count Mode ● NCM with GCT off

● NCM with GCT High

^3H Measurements in water

Instrument	Efficiency (%)	BG (CPM)	Count Mode	E^2/B
Tri-Carb 4910	25.7	1.91	● NCM	346
Tri-Carb 4910	23.0	1.29	● LLCM	410
Quantulus GCT 6220	23.6	1.00	● NCM GCT off	557

● Normal Count Mode ● Low Level Count Mode ● Super Low Level Count Mode ● NCM with GCT off

● NCM with GCT High

^3H Measurements in water

Instrument	Efficiency (%)	BG (CPM)	Count Mode	E^2/B
Tri-Carb 4910	25.7	1.91	● NCM	346
Tri-Carb 4910	23.0	1.29	● LLCM	410
Quantulus GCT 6220	23.6	1.00	● NCM GCT off	557
Quantulus GCT 6220	20.4	0.61	● SLLCM	682

● Normal Count Mode ● Low Level Count Mode ● Super Low Level Count Mode ● NCM with GCT off

● NCM with GCT High

^3H Measurements in water

Instrument	Efficiency (%)	BG (CPM)	Count Mode	E^2/B
Tri-Carb 4910	25.7	1.91	● NCM	346
Tri-Carb 4910	23.0	1.29	● LLCM	410
Quantulus GCT 6220	23.6	1.00	● NCM GCT off	557
Quantulus GCT 6220	20.4	0.61	● SLLCM	682
Quantulus GCT 6220	23.6	0.21	● NCM GCT high	**2652**

● Normal Count Mode ● Low Level Count Mode ● Super Low Level Count Mode ● NCM with GCT off

● NCM with GCT High

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^3H Measurements in water

Detection Limit (Bq/l)	Counting Time (Minutes)	Count Mode
10.0	32.0	Tri-Carb 4910 NCM
10.0	28.0	Tri-Carb 4910 LLCM
10.0	22.0	Quantulus NCM GCT off
10.0	8.0	Quantulus NCM GCT high

Detetection limit according to ISO 11929, $k_{1-\alpha} = k_{1-\beta} = 1.65$, Sample volume 8 ml

^3H Measurements of spiked water

Known Activity* (Bq/l)	Measured Activity (Bq/l)	2 σ Confidence Range (Bq/l)
9.3	9.0	7.7 – 10.1
37.3	36.1	31.5 – 40.5
83.9	82.1	72.0 – 92.0

(*Samples from German Federal Institute of Hydrology)

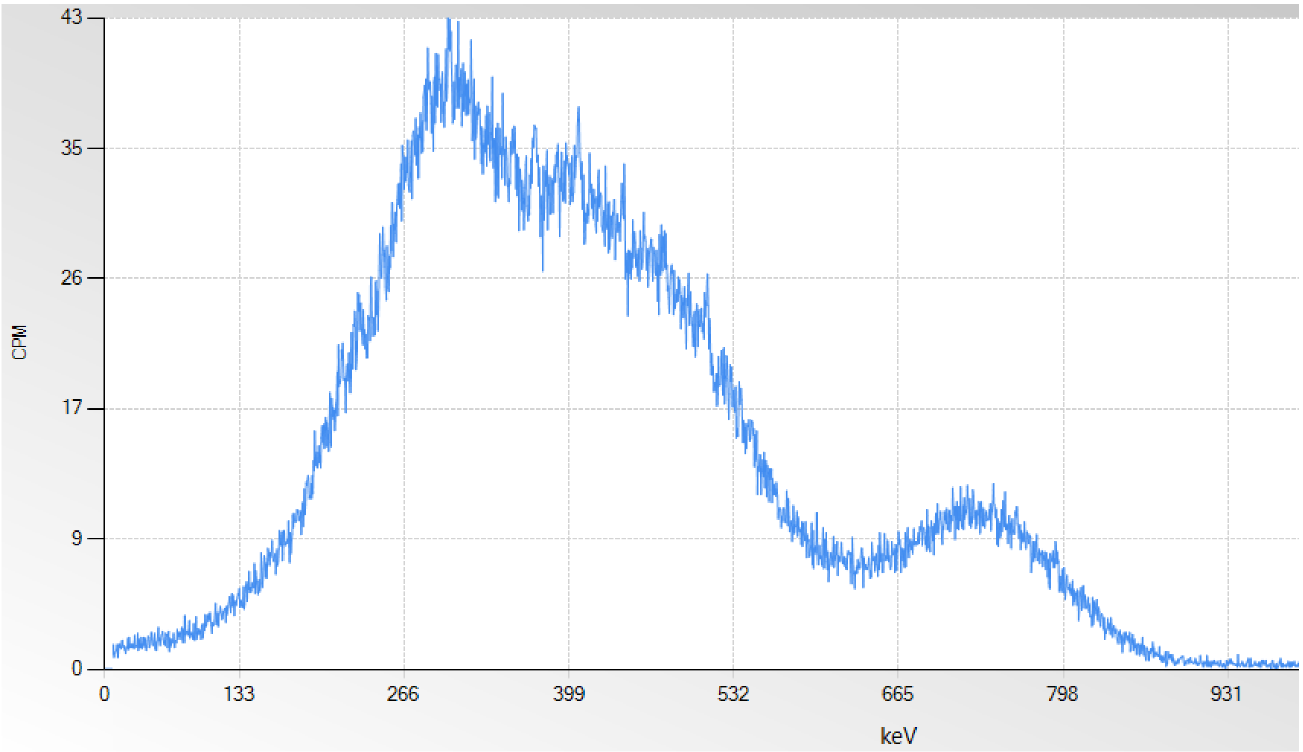
^{222}Rn Measurements in water

Samples:

Water samples (12 ml) measured with Ultima Gold F (10 ml). The sample was shaken 30 seconds and allowed to separate. The measurement started after 3 hours to have equilibrium of the three α–emitter ^{222}Rn, ^{218}Po and ^{214}Po and two β–emitter ^{214}Pb and ^{214}Bi.

Measurements were done using protocols with and without α/β–discrimination.

^{222}Rn Measurements in water



^{222}Rn, ^{218}Po and ^{214}Po three hours after extraction of ^{222}Rn with Ultima Gold F from a ^{226}Ra source in glass vial.

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^{222}Rn Measurements in water

Vial	Efficiency (%)	BG (CPM)	α/β–Discrimination	Energy Window (keV)
Plastic	185.8	0.8	Yes	160 – 650
Glass 1	183.2	0.8	Yes	145 – 840
Glass 2	179.5	0.8	Yes	145 – 840
Glass 1	264.1	0.5	No	20 – 840
Glass 2	275.2	0.5	No	20 – 840

All measurements done with a Quantulus GCT 6220

^{222}Rn Measurements in water

Vial	Detection Limit (Bq/l)	Counting Time (Minutes)	α/β–Discrimination
Plastic	10.0	0.5	Yes
Glass 1	10.0	0.5	Yes
Glass 2	10.0	0.5	Yes
Glass 1	10.0	0.25	No
Glass 2	10.0	0.22	No

All measurements done with a Quantulus GCT 6220

Gross α/β–Measurements in water

Typically 100 to 120 ml drinking water, in samples with low salt content up to 150 ml can be used.
After distillation to dryness and uptake in 8 ml of water this can be measured in 12 ml Ultima Gold LLT. All samples were acidified with nitric acid to pH 1.8
All samples were measured with α/β–discrimination.

Gross α/β–Measurements in water

Sample	CPM	Efficiency (%)	Energy Window (keV)
α–background	0.53	97.8	80 – 400
β–background	0.38	91.7	12 – 800

α–Detection limit 0.036 Bq/l
β–Detection limit 0.032 Bq/l

Sample volume 120 ml, counting time 200 minutes,
$k_{1-\alpha} = k_{1-\beta} = 1.65$

Gross α/β–Measurements in water

Sample	Gross α (Bq/l)	Gross β (Bq/l)
Tap Water 1	< LOD	< LOD
Tap Water 1	< LOD	0.035
Mineral Water 1	0.045	0.045
Mineral Water 2	< LOD	< LOD

All measurements done with a Quantulus GCT 6220

Thank you for your attention

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