

IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

Radionuclides in Food

Analytical Techniques Overview

O. PIERRARD - IRSN

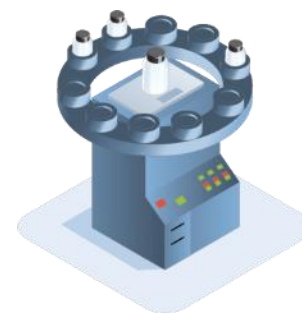
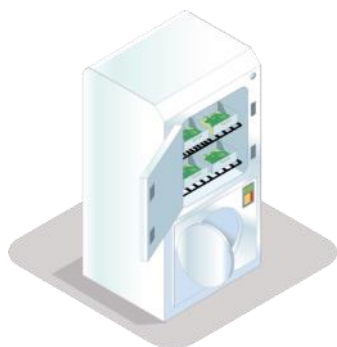
IAEA Training Course INT 5.154

Singapore – October 2017



OBJECTIVES

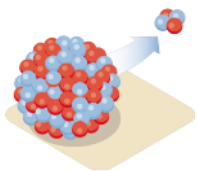
- ▶ To introduce the field of radioactivity measurements in Foodstuff and Drinking water samples
- ▶ A complete introduction to help you better understand the following detailed presentations for each technique



CONTENT



- ❑ Radionuclides of interest
- ❑ Overview of techniques dedicated to each category of radionuclides
- ❑ Sample pretreatment and radiochemistry key points
- ❑ General principles :
 - *Gross α/β counting*
 - *α particle spectrometry*
 - *γ ray spectrometry*
 - *Liquid scintillation counting*
 - *Mass spectrometry*
- ❑ Examples of analysis plan with key steps (water, milk, foodstuff, ^3H)
- ❑ Some consideration to take into account in post accidental situations



Radionuclides of interest

In FOOD

^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Am

(CODEX)

^{90}Sr , ^{106}Ru , ^{129}I , ^{131}I , ^{235}U



^{35}S , ^{60}Co , ^{89}Sr , ^{103}Ru , ^{134}Cs , ^{137}Cs , ^{144}Ce , ^{192}Ir

^3H (OBT), ^{14}C , ^{99}Tc

Mostly
Artificials

In Drinking Water

(WHO)



^3H , Gross alpha, Gross beta, ^{40}K

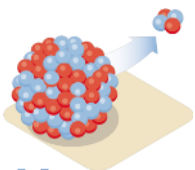
^{14}C

^{90}Sr , ^{131}I , ^{134}Cs , ^{137}Cs , ^{238}U

^{226}Ra , ^{228}Th , ^{230}Th , ^{232}Th , ^{234}U , ^{239}Pu , ^{241}Am

^{210}Pb , ^{210}Po , ^{228}Ra

« Mostly »
Radionuclides
of natural
origin



Radionuclides of interest

How can we quantify them ?

Decays, rays energies and intensities are described in tables:

table de radionucléides

$^{137}_{55}\text{Cs} \rightarrow ^{137m}_{56}\text{Ba} \rightarrow ^{137}_{56}\text{Ba}$

SCHEMA DE DESINTEGRATION

Le ^{137}Cs se désintègre par émission β^- vers le niveau fondamental de ^{137}Ba ainsi que vers le niveau isomère de 661 keV.

table de radionucléides

$^{137}_{55}\text{Cs} \rightarrow ^{137m}_{56}\text{Ba} \rightarrow ^{137}_{56}\text{Ba}$

CONSTANTES NUCLEAIRES

$T_{1/2} (^{137}\text{Cs}) : (30,15 \pm 0,06) \text{ ans}$
 $T_{1/2} (^{137m}\text{Ba}) : (2,564 \pm 0,002) \text{ minutes}$
 $Q : (1173,2 \pm 0,9) \text{ keV}$

TRANSITIONS β^-

Energie keV	Intensité %	Nature	log ft
$661,662 \pm 0,9$	$94,6 \pm 0,3$	interdite 1 ^{er} ordre unique	9,1
$1173,2 \pm 0,9$	$5,4 \pm 0,3$	interdite 2 ^e ordre	11,2

TRANSITION γ

Energie keV	Intensité %	Multipolarité	μ_K	μ_L	μ_S
$661,662 \pm 0,003$	$94,6 \pm 0,3$	M4	$0,0881 \pm 0,0009$	$0,0187 \pm 0,0008$	$0,1007 \pm 0,0010$

CONSTANTES ATOMIQUES (Ba)

$\mu_K : 0,901 \pm 0,026$
 $\mu_L : 0,10 \pm 0,01$
 $\mu_{KL} : 0,89 \pm 0,05$

PHOTONS X

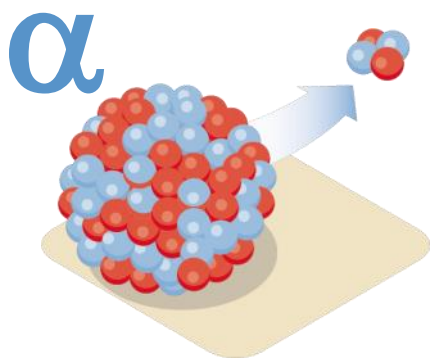
X_K	Energie keV	Intensité relative
$K\alpha_1$	31,8171	54,3
$K\alpha_2$	32,1936	100
$K\beta_1$	36,3040	29,6
$K\beta_2$	36,3782	
$K\beta_3$	37,257	7,0
$K\beta_{1,III}$	37,426	
X_L	3,95 – 5,97	

ELECTRONS AUGER

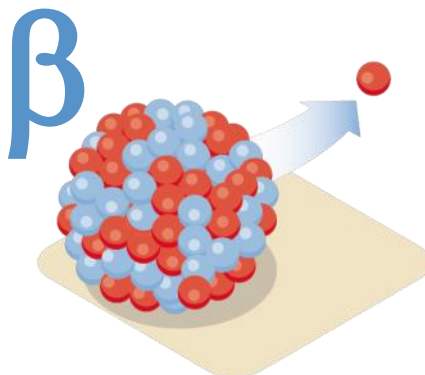
Auger K	Energie keV	Intensité relative
KLL	25,31 – 26,78	100
KLX	30,09 – 32,16	47
KXY	34,84 – 37,41	6,5
Auger L	2,6 – 5,9	

Radionuclides of interest

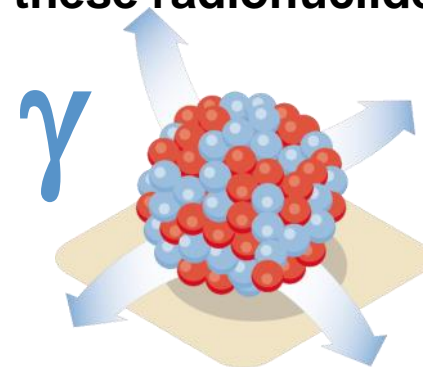
Main types of radiation considered for quantification of these radionuclides



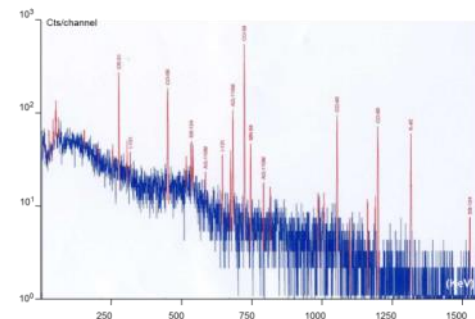
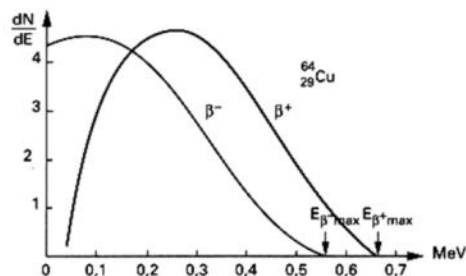
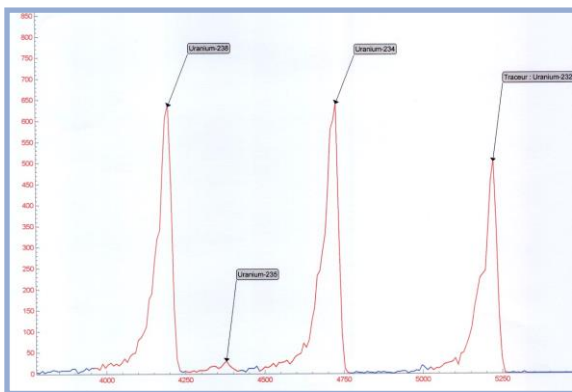
^{210}Po , ^{230}Th , ^{228}Th , ^{226}Ra ,
 ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Am ,
 ^{235}U , ^{244}Cm ,
 ...



^3H , ^{14}C , ^{35}S , ^{89}Sr ,
 ^{90}Sr , ^{241}Pu
 ...



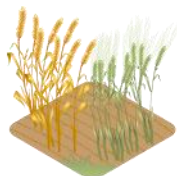
^7Be , ^{40}K , ^{131}I , ^{134}Cs ,
 ^{137}Cs , ^{210}Pb , ^{228}Ra
 ...



Matrixes of interest



Leafy vegetable



Cereals



Mushroom



Milk



Algae



Mixed Diet



Meat



Crustaceans



Water



Fruits



Molluscs



Beverage



Vegetables



Fish

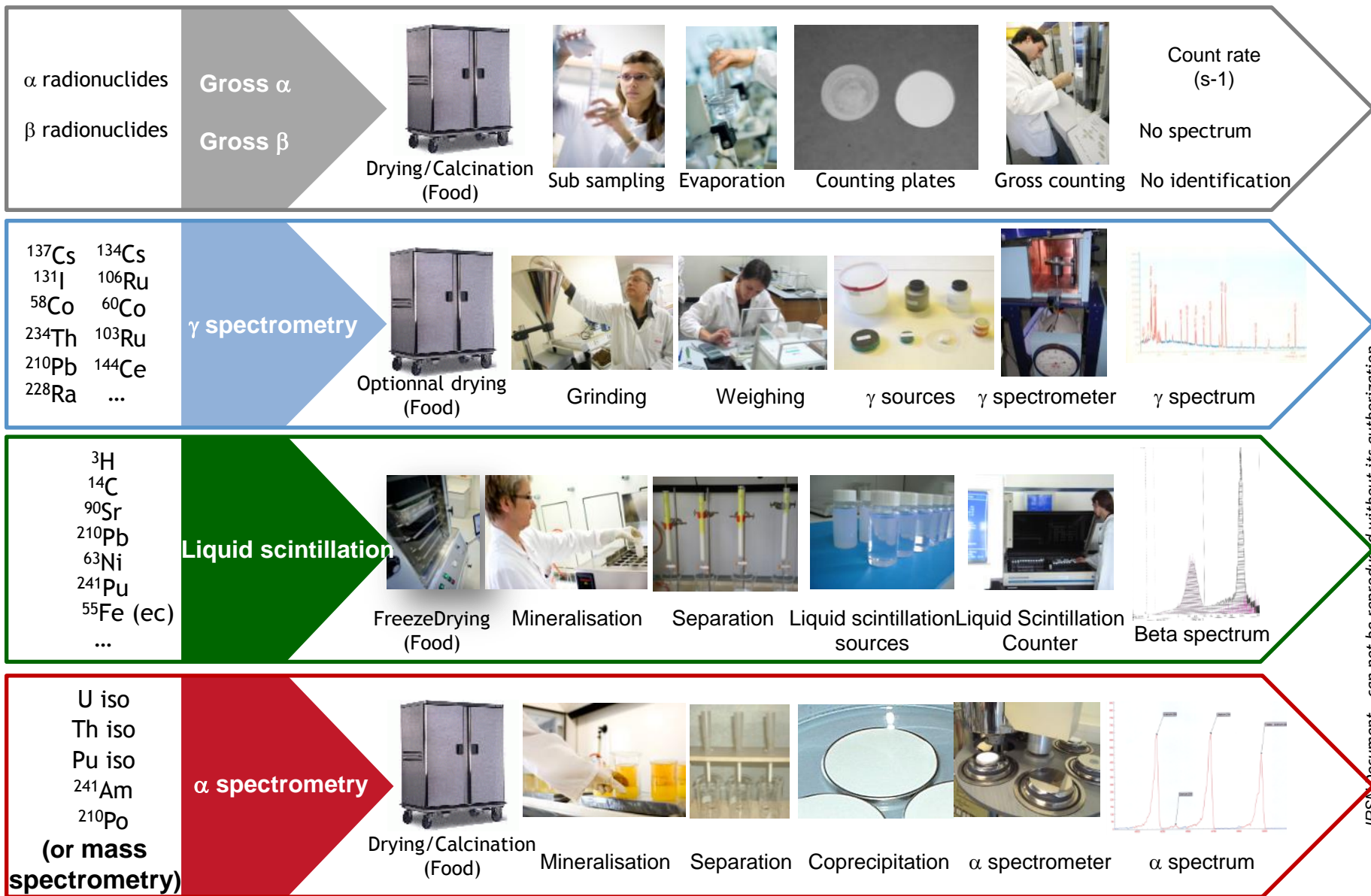


Other foodstuff

Matrixes x Radionuclides = Many possible combinations = Different analytical processes

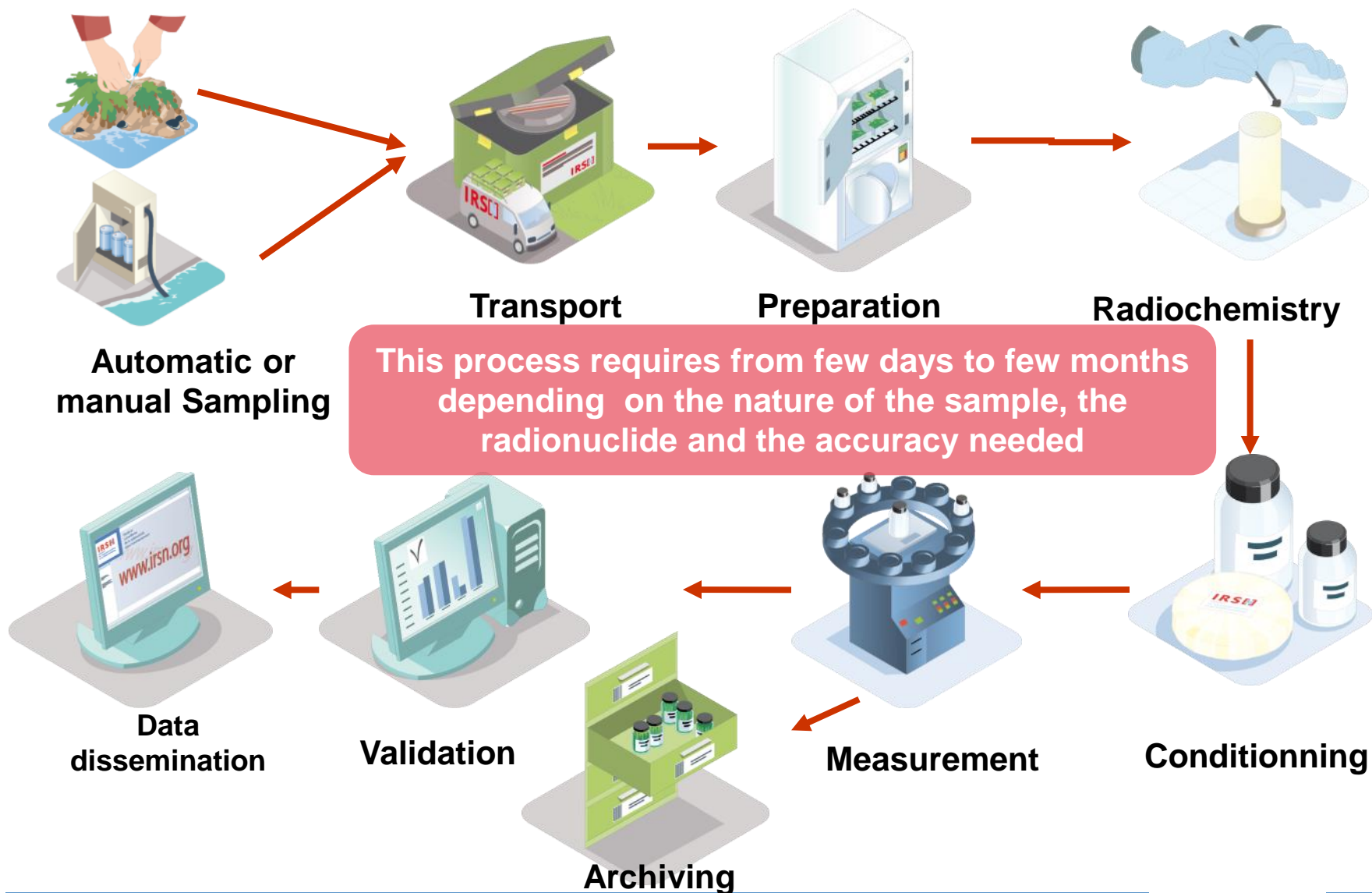


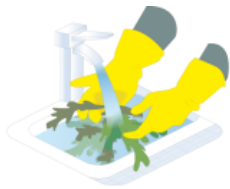
Most classical analytical processes overview (not exhaustive !)



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Analytical process





First preparation of the sample

Except for gamma spectrometry, samples received in the laboratory may not be in the proper physical form for analysis. Preparation of samples is generally needed.

After **control** and **registration**, the samples received in the laboratory must be **properly stored** to avoid degradation, cross contamination, loss of volatile radionuclides

The laboratory sample preparation techniques include all the **physical manipulations** (drying, filtration, grinding, mixing, ashing...) **needed prior to the analysis** to reduce the weight of the sample or to transform it in the proper form. **Precise measurements** of the (fresh, dry, ash) weight are necessary for calculations of radionuclides concentration.

its authorization



The amount of material collected is generally greater than that required for the determination. In most cases, prior to the activity measurement, **sub-sampling is required** (need a efficient **homogenization** before !)

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Drying

- ▶ Most analytical results for solid samples should be reported on a dry-mass basis ($\text{Bq}/\text{kg}_{\text{dry}}$) **avoiding variability** (soil, bioindicators...)
- ▶ Drying **reduce the weight** (and thus allow lowering detection limits) and volume of the sample
- ▶ Drying allow **extended storage**



The temperature must be carefully controlled to avoid losses of radionuclides such as I, Po, Ru...





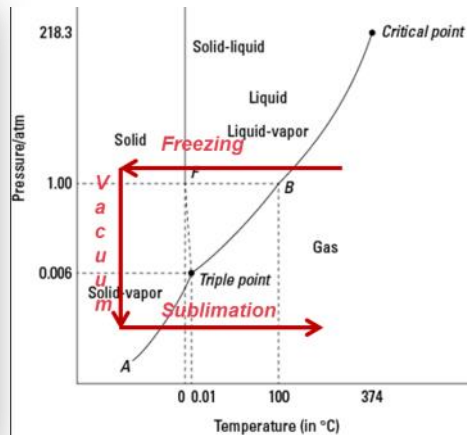
Freeze-drying

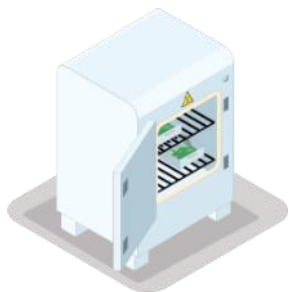
For the concentration of solid matrixes and to separate liquid / solide fraction

Freeze-Drying allows :

- ▶ dehydration of samples without heating
- ▶ to preserve the sample
- ▶ to recover the water present in the sample.

Application : measurement of free ^3H (HTO in the water extracted) and organic bound ^3H (OBT), ^{14}C





Calcination

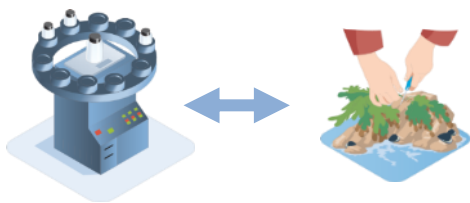
- ▶ Ashing **reduce** the weight and volume of the sample and allow extended storage
- ▶ Ashing is needed to **prepare** a sample for subsequent chemical process (Radiochemistry = Mineral Chemistry !)

As for drying, the temperature must be carefully controlled to avoid losses of radionuclides



Potential loss of radionuclides of volatiles elements, such as I, Po, Ru and Cs



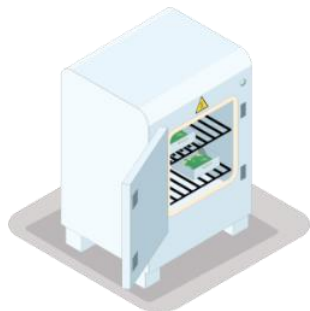


Quantity for analysis Quantity to be sampled

The sample quantities to be taken depend on the detection limits desired, the number of analysis to be performed and the nature of the sample

	Algae Aq. Plants	Terrestrial Plants	Fruits Vegetables	Aquatique Fauna	Cereals	Meat	Milk
Mass ratio (Fresh / Dry)	5	20	10	7	1	4	10
Mass ratio (Dry / Ashes)	7	10	7	10	70	30	15
Mass ratio (Fresh / Ashes)	35	200	70	70	70	120	150
Quantity (g fresh) needed to obtain 100 g dry <i>(Gamma spectrometry, ^3H, ^{14}C, ^{210}Po)</i>	500	2000	1000	700	100	400	1000
Quantity (g fresh) needed to obtain 20 g of ashes <i>(Radiochemistry : Pu, Am, U, Sr, Cm, Th, Ra)</i>	700	4000	1400	1400	1400	2400	3000

Order of magnitude (IRSN)



Grinding

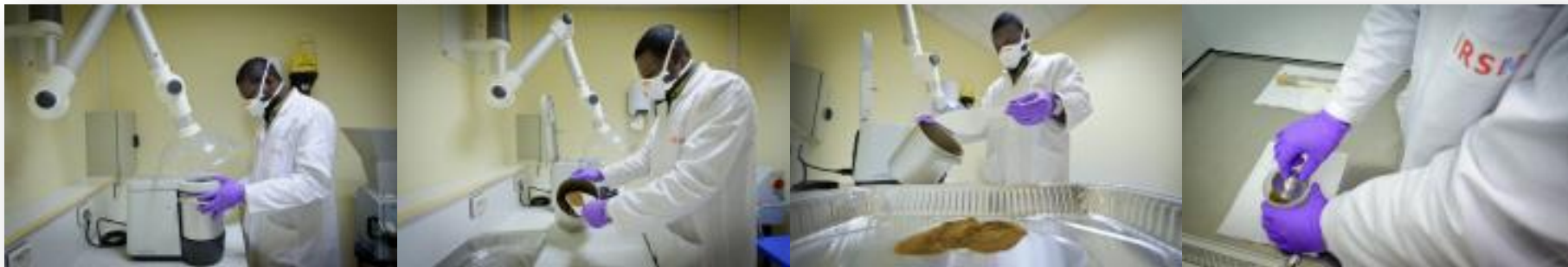
This step allows to :

- ▶ **Homogenize** the sample before sub-sampling
- ▶ **Facilitate** the subsequent operations of compaction and the operations of acid attack in radiochemistry for the mineral matrixes (facilitates the chemical solution)
- ▶ **Reduce** the vacuum in the samples and thus optimizes the quantity put in a geometry.



Different grinders are used depending on the hardness of the sample and the amount to be crushed : mortar, mixer mill hammer cutter mill, ...

- *For a 20 g sample the particle size should not exceed about 200 μm .*
- *For a 5 g sample the particle size should not exceed about 140 μm .*





Radiochemistry

To identify and quantify radionuclides in food samples at low activity levels, it is generally not possible to achieve this goal using direct measurement of the sample.

A “radiochemistry” step is often required to **extract/separate, concentrate and prepare a source** in a geometry adapted to count the radionuclide of interest.

Most radiochemical analyses require that the radionuclide be in **aqueous solution**.



The first step of an analysis is the dissolution of the sample. For food solid sample, it requires the prior calcination step





Radiochemistry - Dissolution

Total dissolution of many samples requires vigorous conditions to release the radionuclides from their natural matrix. For the determination of actinides it is important to destroy all the organic matter in order to prevent any possibility of the formation of stable complexes which are very insoluble.

3 basic techniques :

▶ Wet ashing (*classical hot plate acid dissolution*)

Different acids are used alone or in combination to decompose specific compounds that may be present in the sample (next slide)

▶ Acid digestion (*using μ wave oven*)

Faster, cleaner and more reproducible but constraints on sample size resulting from vessel pressure limitations

▶ Fusion

Employed for samples difficult to dissolve in acids. The sample is melted by heating with a salt





Radiochemistry - Dissolution

Examples of acids used for wet ashing

ACID	TYPICAL USES
Hydrofluoric acid, HF	Removal of silicon and destruction of silicates; dissolves oxides of Nb, Ta, Ti, Zr and Nb, Ta, Zr ores.
Hydrochloric acid, HCl	Dissolves many carbonates, oxides, hydroxides, phosphates, borates and sulfides, dissolves cement.
Sulphuric acid, H ₂ SO ₄	Dissolves oxides, hydroxides, carbonates, and various sulfides ores; hot concentrated acid will oxidize most organic compounds.
Phosphoric acid, H ₃ PO ₄	Dissolves Al ₂ O ₃ , chromes ores, iron oxides ores, and slag.
Nitric acid, HNO ₃	Oxidizes many metals and alloys to soluble nitrates; organic material oxidized slowly.
Perchloric acid, HClO ₄	Extremely strong oxidizer; reacts violently or explosively to oxidize organic compounds; attacks nearly all metals.



Radiochemistry – Separation/extraction

Separation involve mainly classical chemical procedures :

- ▶ **Distillation**
- ▶ **Complexation**
- ▶ **Solvent extraction**
- ▶ **Chromatography**
- ▶ **Precipitation and co-precipitation**

Considering that number of atoms of the radionuclide to be quantified is small, adding a carrier can be necessary to raise the chemical concentration of the analyte to the point where it can be separated using conventional techniques. An isotopic carrier can also be used as a tracer to determine the chemical yield of the analyte. Ex : adding ^{85}Sr for ^{90}Sr analysis.



It is important to add the carrier to the sample as early as possible in chemical process. To perform properly, a carrier or a tracer must have the same oxidation state and chemical form as the analyte.





Radiochemistry – Source preparation

Measurements of nuclear decay emissions (α, β, γ) and atoms counting need specific source preparation methods:

- ▶ **Simple evaporation** using a heat source can be used when a high degree of uniformity of the deposit is not a requirement

Easy, fast, and adequate for many types of measurements.
(water samples for gross counting)



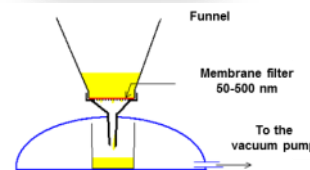
- ▶ **Electrodeposition on a metallic surface** from an aqueous solution - produce thin and uniform sources

Appropriate for preparing a sources, especially for high resolution spectrometry of actinides (U, Pu, Th, Am, and Np).
Require to be monitored with a tracer.



- ▶ **Micro-precipitation for α spectrometry.**

Highly insoluble lanthanide added (0.1 to 1 μg), addition of HF to precipitate and filtration to separate co-precipitate from the supernate.



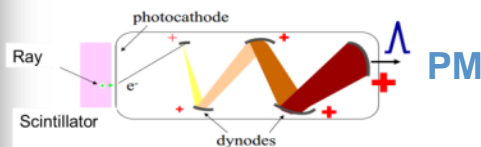
Gross α

Gross β

In radiation protection, sometimes, the details on the isotopic composition are not so much critically important. Using gross α/β counting is simpler and faster and used for example for the screening (drinking water, after an accident....)

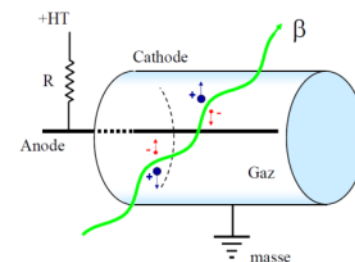
The gross alpha activity is provided mainly by 2 types of detectors:
(calibrated by ^{241}Am or ^{239}Pu)

SOLID SCINTILLATION COUNTER (ZNS)



1. Emission of light as a result of the ionization by alpha particles of the silver-activated zinc sulfide
2. Collection of light and its conversion into electrical pulses is obtained using photomultiplier tubes or photodiodes.

PROPORTIONAL COUNTER



1. By interacting with the gaz contained in the detector, the particles cause ionization. The electrons released are collected by the anode subjected to a continuous electric voltage.
2. The output signal is proportional to the number of ions created in the detector

Gross α

Gross β

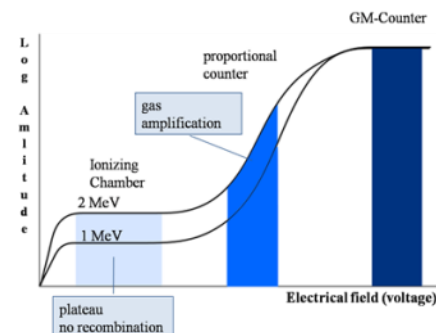
The gross beta activity follows the principle of global alpha measurement, unlike the standard source which is composed of ^{90}Sr and ^{90}Y (pure beta emitters). The counter may be of the proportional counter (with a different HV) or GM counter type.

PROPORTIONAL COUNTER



As for gross α counting :

- The method can be used for fast screening
- The preparation of sample requires usually in both of the methods evaporation and drying of sample.



As for gross α counting :



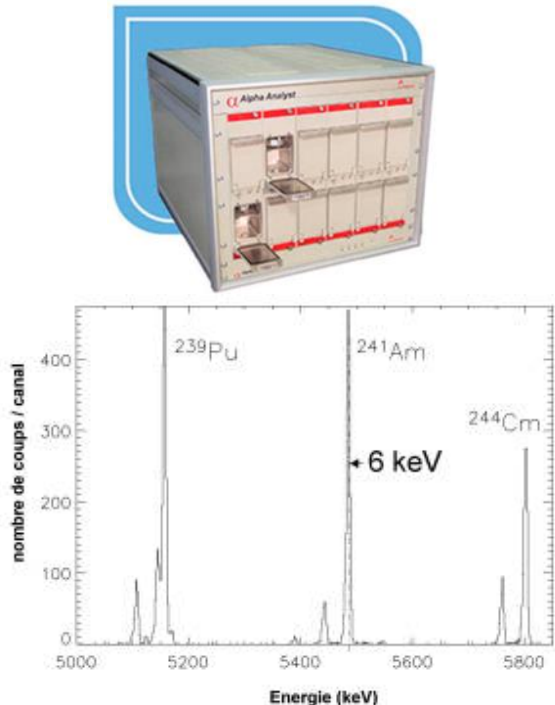
- ▶ Identification of radionuclide is impossible
- ▶ The main problem of traceability to activity standards is due to self-absorption of the emitted particles in the evaporated material. This is critically important to α particles and to low energy β particles.
- ▶ The results must be associated with their counting dates / no possibility to calculate the activity at a date prior to the counting date

α spectrometry

α particle spectrometry is a powerful tool to analyse α emitting radionuclides in various environmental sample types and became a routine analytical technique.

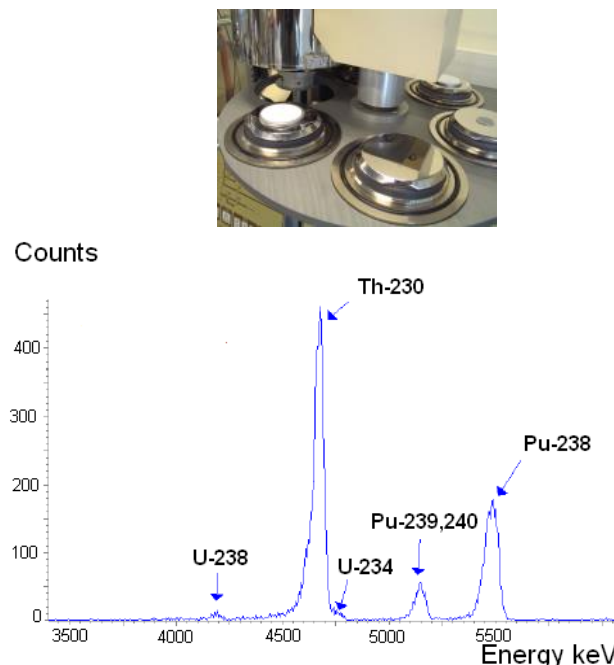
U iso, Th iso,
Pu alpha iso,
 ^{241}Am , ^{210}Po , ...

SEMICONDUCTOR DETECTOR SI



Alpha spectrum of a mixed source measured by a Si detector

GRIDDED IONIZATION CHAMBER



Alpha spectrum of a mixed source measured by a gridded ionization chamber

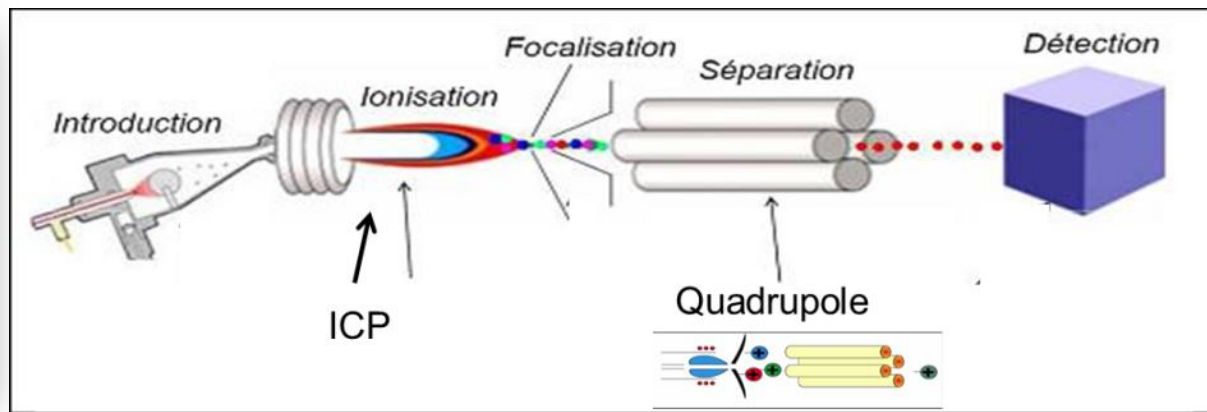
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Mass spectrometry ICP-MS

Inductively Coupled Plasma Mass Spectrometry

^{241}Am , ^{239}Pu ,
 ^{240}Pu , ^{238}U ,
 ^{232}Th ..

Mass spectrometric techniques, which apply direct atom counting techniques and allow good sensitivity are mainly applied for the detection of long-lived radionuclides in environmental samples



Ions are created in the **ICP** and transferred into the **Quadrupole** mass spectrometer. After separation according to the mass to charge ratio, ions are collected at the detector and the ion beam intensities are reported to the data system.

α spectrometry



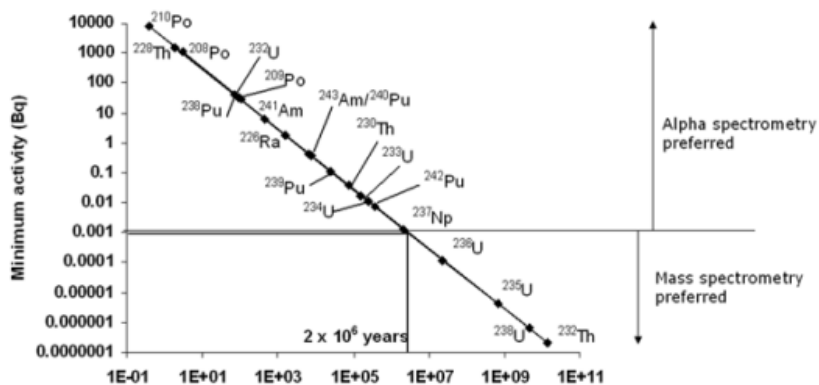
VS



Mass spectrometry
ICP-MS

Radionuclides

^{210}Po , ^{241}Am , ^{238}Pu ,
 ^{244}Cm , ^{228}Th , ^{230}Th ...



Long half-life :
 ^{235}U , ^{238}U , ^{232}Th ..

Sensitivity

Advantages

Sensitivity
Multi-elements
Stable element
Time

Disadvantage

Requires specific radiochemistry,
Interferences
Preparation time (~ 3 to 4 weeks)

Radiochemistry
Interferences
Cost

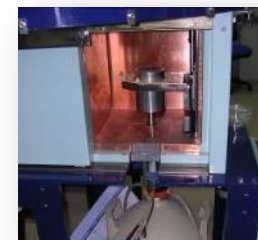
γ spectrometry

γ spectrometry is one of the most popular measurement techniques to determine nuclide specific activities in samples :

${}^7\text{Be}$, ${}^{40}\text{K}$, ${}^{58}\text{Co}$,
 ${}^{60}\text{Co}$, ${}^{106}\text{Ru}$, ${}^{129}\text{I}$,
 ${}^{131}\text{I}$, ${}^{134}\text{Cs}$, ${}^{137}\text{Cs}$,
 ${}^{144}\text{Ce}$, ${}^{228}\text{Ra}$,...

In many cases, γ ray spectrometry allows both qualitative and quantitative determination of the γ emitters radionuclides in the sample without the need of chemical separations. It allows multi-element Identification and it is a non-destructive counting method. Measurements using γ spectrometry vary according to :

- Sample type and Radionuclides of interest.
- Detection efficiency.
- Required uncertainty or detection limit.



Simple but : to get reliable activity results it is very important that the users have a good knowledge of this technique., because it requires :

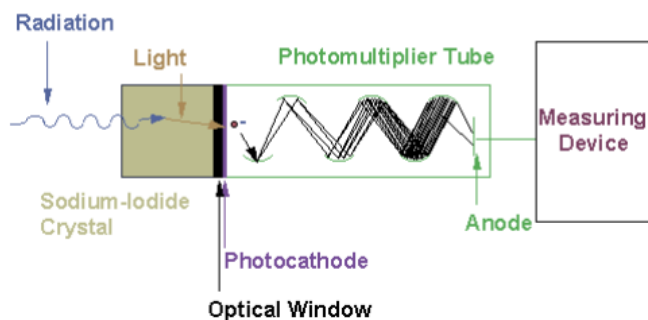


- **Multiplicity of Calibrations (Calibration Curve / Geometry / Matrix / Detector)**
- **Peaks-sums for multi-line elements.**

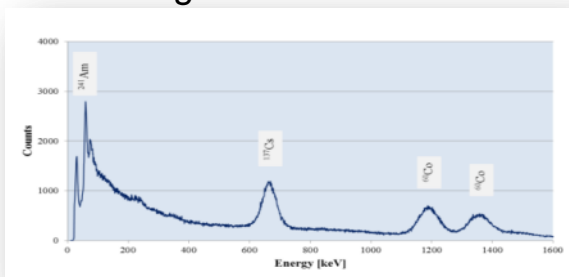
γ spectrometry

The selection of the type and shape of the detector is much related to the radionuclides of interest (energy of emitted γ rays), the sample types.

SCINTILLATION DETECTOR



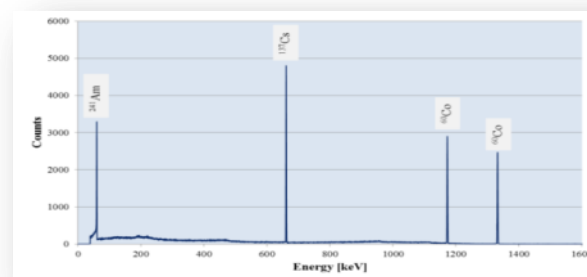
- No cooling is needed. higher efficiencies, cheaper.
- The energy resolution is poor, and the detection limits of these detectors are too high.
- This type of detectors is often used for the rapid determination of higher levels



SEMICONDUCTOR CRYSTAL



- HP-Ge detectors are preferred in the field of radioactivity measurement in environmental samples radionuclides.
- The standard shape, where the sample is placed in front or on top of the detector.

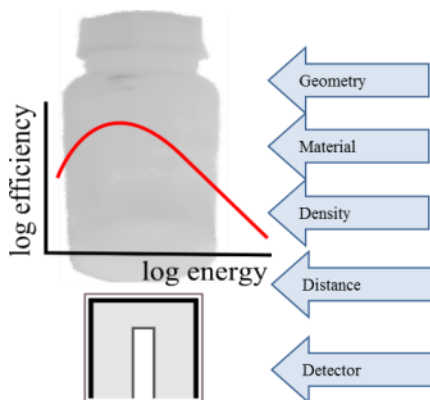
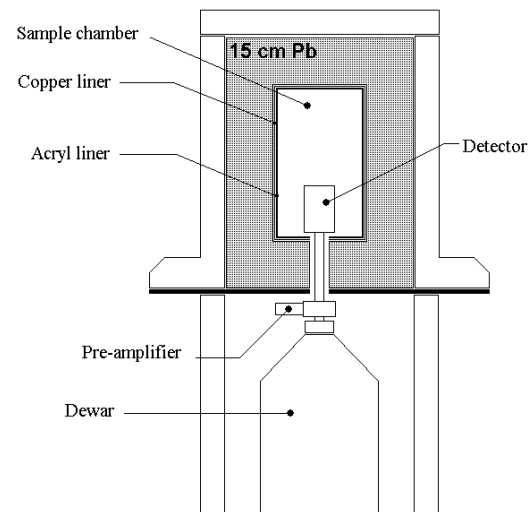


γ spectrometry

For the reduction of the background of a γ spectrometer, a passive shielding with a lead shield is classically used

This shield consists typically of 10 to 15 cm lead. The lead should be a so-called low level lead, which has a very low content of natural radionuclides.

Additional copper liner should be used, only if naturally occurring radionuclides are of interest.



The energy calibration is the first step in the calibration procedure of a γ ray spectrometer.

The efficiency calibration is needed. It depends on

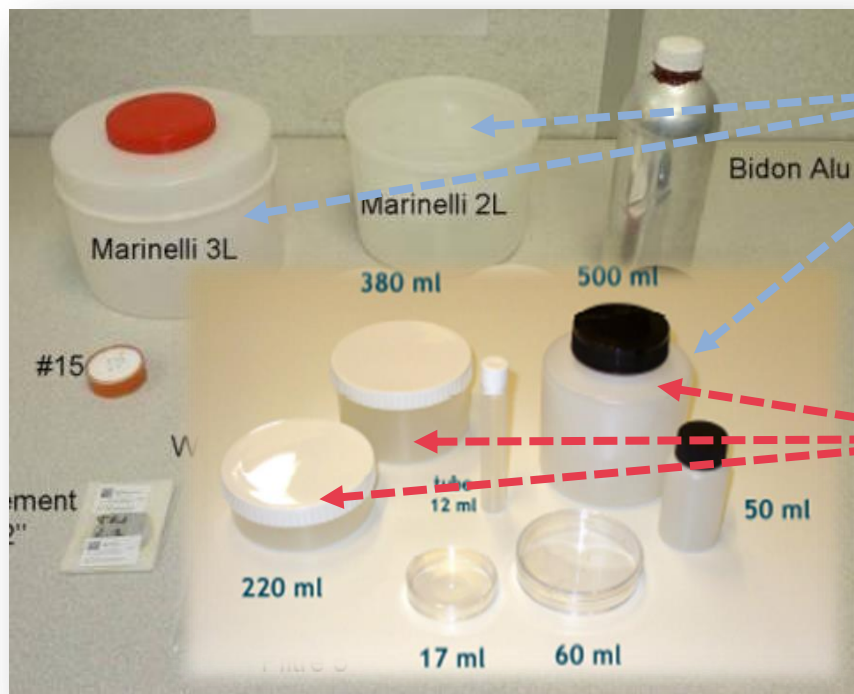
- The energy
- The detector parameters
- The material of the sample
- The sample geometry

The classic way to do a calibration is to count standard solution in the right geometry

γ spectrometry

The sample geometries must be selected for the matrices of interest. They include containers suitable for water, vegetation, milk, fresh vegetables, foods ...

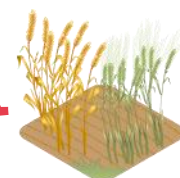
Some kinds of geometries used for gamma spectrometry (IRSN)



Milk



Beverage



**Solid foodstuff
(mostly dried of ashes)**



The geometries must also be calibrated for the densities of the samples of interest as a function of γ ray energy



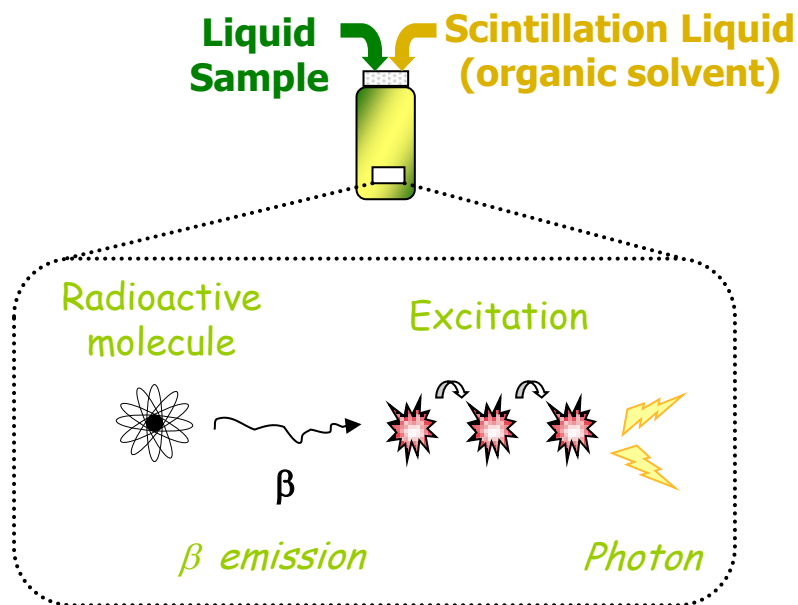
IRSN STANDARDS AND INTERCOMPARAISONS

Liquid scintillation

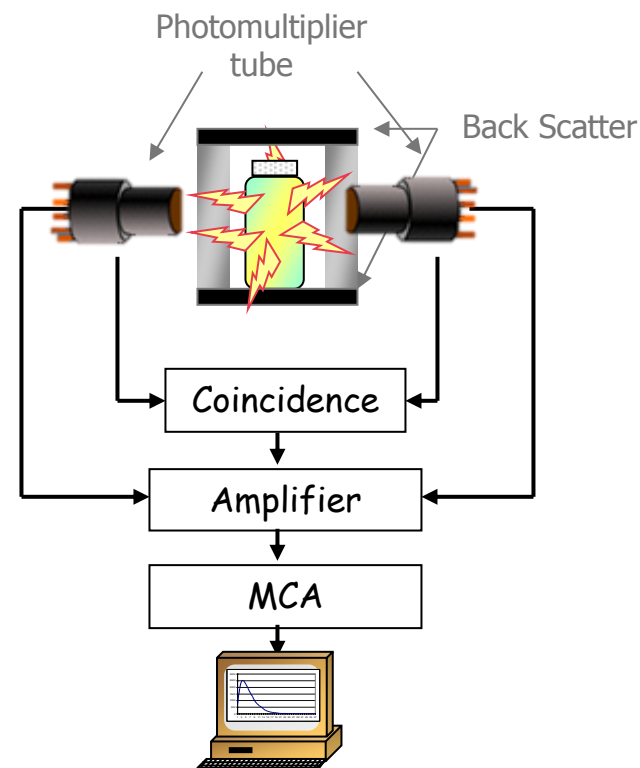
LSC is widely use for pure β particle emitter. It is also useful for determining α emitting radionuclides (such as $^{239+240}\text{Pu}$ in environmental samples).

^3H , ^{14}C , ^{90}Sr ,
 ^{63}Ni , $^{55}\text{Fe(ec)}$,
 ^{210}Pb , ^{241}Pu ...

PREPARATION



COUNTING



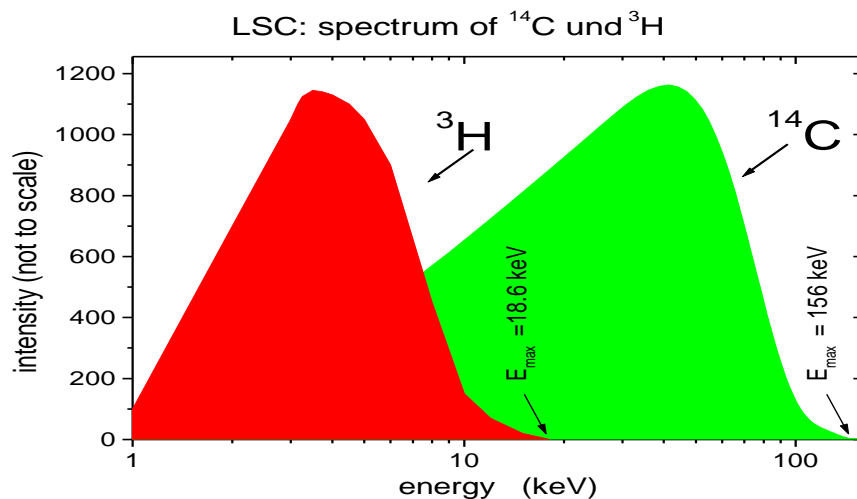
Liquid scintillation

LSC is a spectrometric method but several β - emitters can't be analyzed simultaneously because β - decay produces continuous spectra that are more or less overlapping with each other.

β emitters exhibit very different energies ranging from a few keV (^3H , ^{241}Pu) to several MeV (^{90}Y , ^{212}Pb) and therefore highly different counting efficiencies are resulting for LSC applications.

Absolute efficiency calibration with traceable radionuclide solutions is a prerequisite in LSC because there is a strong dependency of the counting efficiency on :

- Energy of the β emitter.
- Cocktail composition.
- Degree of quenching of the sample.



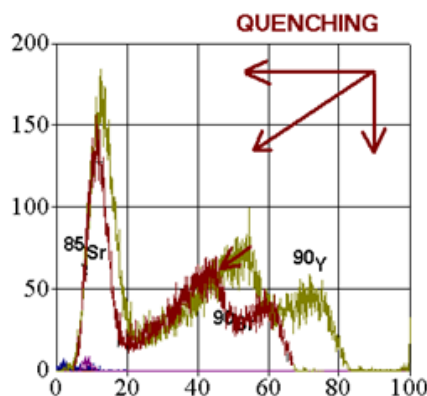
Liquid scintillation spectrum of β -emitting ^{14}C and ^3H in organic solution mixed with a liquid scintillation cocktail.



Liquid scintillation

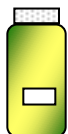
Quenching refers to any mechanism which reduces the amount of light being emitted from the vial.

- Chemical quenching occurs when the light production process is reduced by chemical interferences
- Optical quenching occurs after the scintillation process has taken place
- In colored cocktails the secondary light is absorbed, or scattered by the color molecules on its passage through the cocktail medium towards the PMT's.
- Another important physical effect is deflection of the photons causing longer wave lengths of the photons

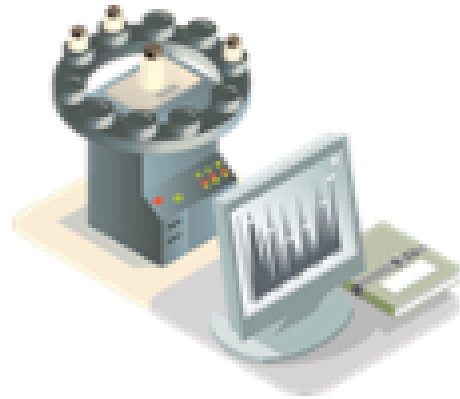


Scintillation liquids must enable high sample load capacities and accept strong acidic solutions without phase separation after cocktail preparation.

Specific cocktail solutions have been developed for :



- Good α/β separation.
- Dissolving organic material such as biological tissue or cellulose based filters.
- Trapping volatile products such as $^{14}\text{CO}_2$ from combustion of organic material.
- For measuring fine grained precipitates or suspensions, gelling scintillators can be taken.



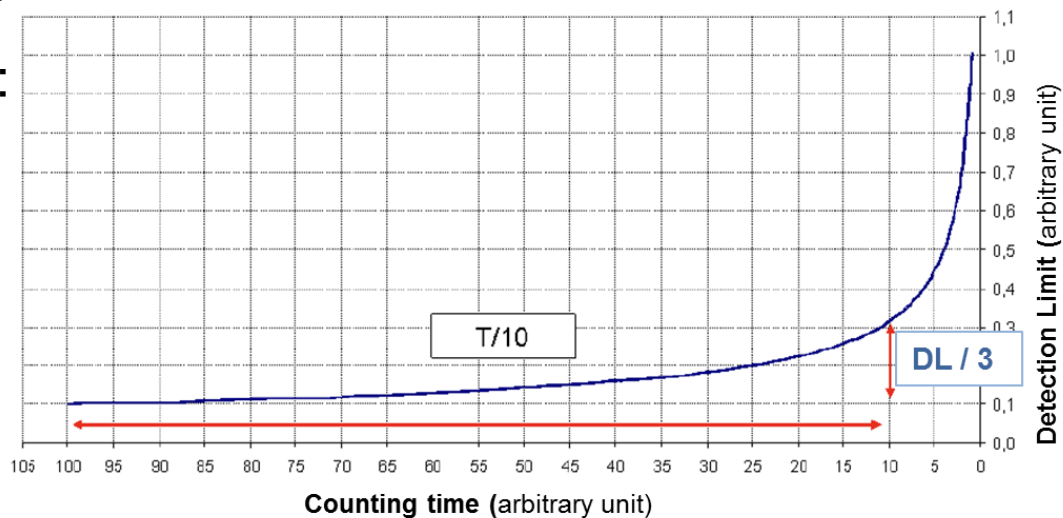
Some General Considerations



Detection Limit for Sample Analysis

Main parameters of influence on LD:

- Apparatus and its environment
- Efficacy of radiochemistry
- Sample activity
- Sample weight
- Counting time :



Ex: Counting time divided by 10 \Rightarrow LD divided by 3



Detection Limit for Environmental Sample Analysis

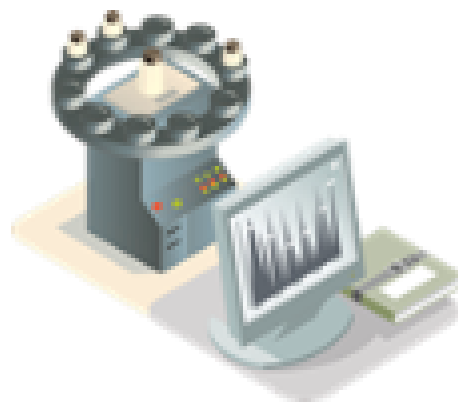
Nuclides	Water		Soil	
	Typical lower limit of detection* (Bq/L)	Typical sample volume (L)	Typical lower limit of detection (Bq/kg)	Typical sample mass (g)
³ H (HTO)	10	10 ⁻²		100
⁵⁴ Mn	0.5	10	2	100
⁵⁹ Fe	1	10	4	100
⁶⁰ Co	0.6	10	2	100
⁶⁵ Zn	1	10	4	100
⁹⁰ Sr	0.1	10	2	100
⁹⁵ Zr- ⁹⁵ Nb	0.4	10	4	100
¹³⁷ Cs	0.6	10	2	100
²²⁶ Ra	4 x 10 ⁻³	1	1	1
²³² Th	1 x 10 ⁻³	1	1	1
²³⁸ U	0.1	1	1	1
²³⁹ Pu	4 x 10 ⁻⁴	100	0.1	50
²⁴¹ Am	1x 10 ⁻³	100	0.1	50

« In general the detection limit should be a small fraction of the action level (1-10%) for a specific radionuclide » (IAEA – 1989)



Examples of commonly performed measurements and activity ranges

	Water	Solid samples
Gamma spectrometry (depending on the radionuclides)	$10^{-3} < A < 100 \text{ Bq.l}^{-1}$	$1 < A < 1000 \text{ Bq.kg}^{-1}$
Gross alpha	$0.025 < A < 30 \text{ Bq.l}^{-1}$	$100 < A < 10000 \text{ Bq.kg}^{-1}$
Gross beta	$0.15 < A < 30 \text{ Bq.l}^{-1}$	$300 < A < 10000 \text{ Bq.kg}^{-1}$
^3H	$10 < A < 1000 \text{ Bq.l}^{-1}$	$1 < A < 10000 \text{ Bq.kg}^{-1}$
^{14}C	$10 < A < 1000 \text{ Bq.l}^{-1}$	$1 < A < 10000 \text{ Bq.kg}^{-1}$ (of carbon)
$^{90}\text{Sr}/^{90}\text{Y}$	$0.001 < A < 10 \text{ Bq.l}^{-1}$	$1 < A < 1000 \text{ Bq.kg}^{-1}$
Other pure beta emitters (^{63}Ni , ^{241}Pu , etc.)	$5 < A < 1000 \text{ Bq.l}^{-1}$	
Isotopic uranium and isotopic thorium	$0.01 < A < 20 \text{ Bq.l}^{-1}$	$1 < A < 2000 \text{ Bq.kg}^{-1}$
^{226}Ra	$0.04 < A < 1000 \text{ Bq.l}^{-1}$	$0.04 < A < 1000 \text{ Bq.kg}^{-1}$
Isotopes of Pu and Am	$0.01 < A < 20 \text{ Bq.l}^{-1}$	$1 < A < 2000 \text{ Bq.kg}^{-1}$



Examples of analysis plan and associated key steps

- Water
- Milk
- Foodstuff
- ^3H



Key steps in water analysis



Water(500 mL)

Aliquoting 100 ml

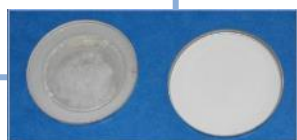
Aliquoting 100 ml

Aliquoting 10 ml

Aliquoting 10 to 70 ml

Evaporation

Deposit on stainless steel cup



+ ZNS screen

SS Counter



Proportional Counter

Gross β

Gross α

AA analysis (stable element)



K (⁴⁰K)

Filtration

Distillation

LS Counting

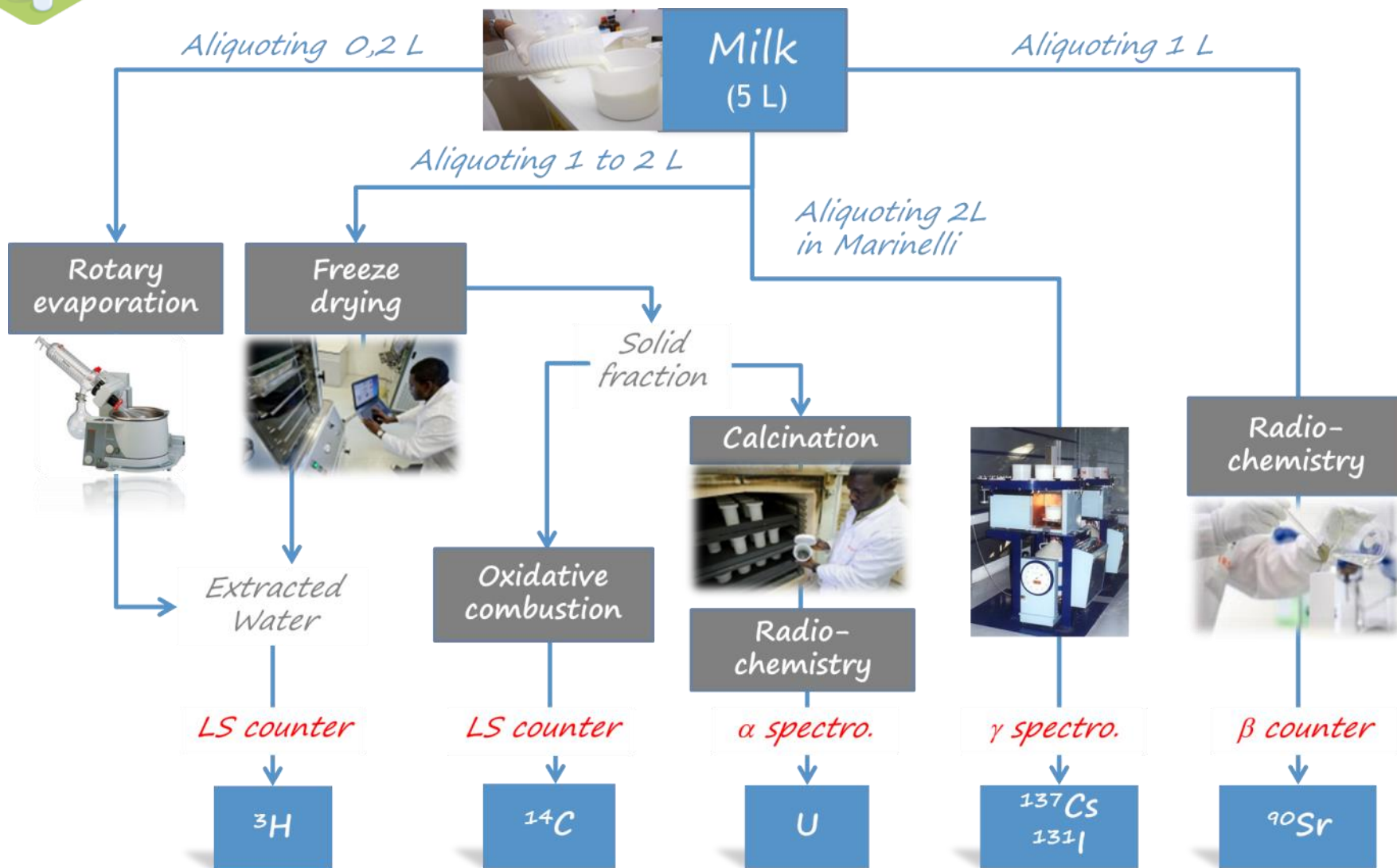


³H

$$\text{Residual gross } \beta \text{ activity (Bq / L)} = \text{gross } \beta \text{ (Bq / L) activity} - 27.9 * [\text{K}] \text{ (g / L)}$$



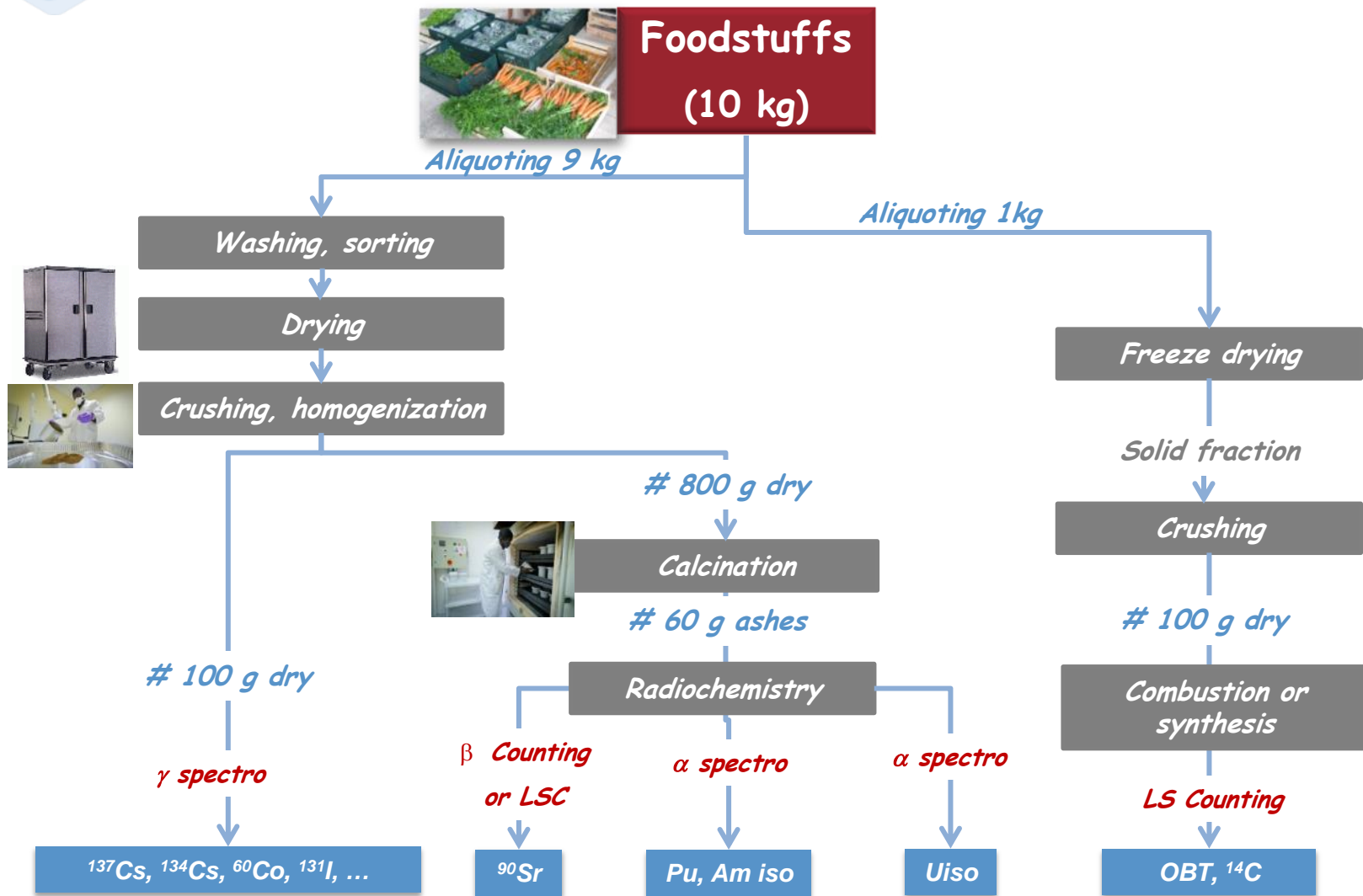
Key steps in Milk analysis



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Key steps in Foodstuff analysis

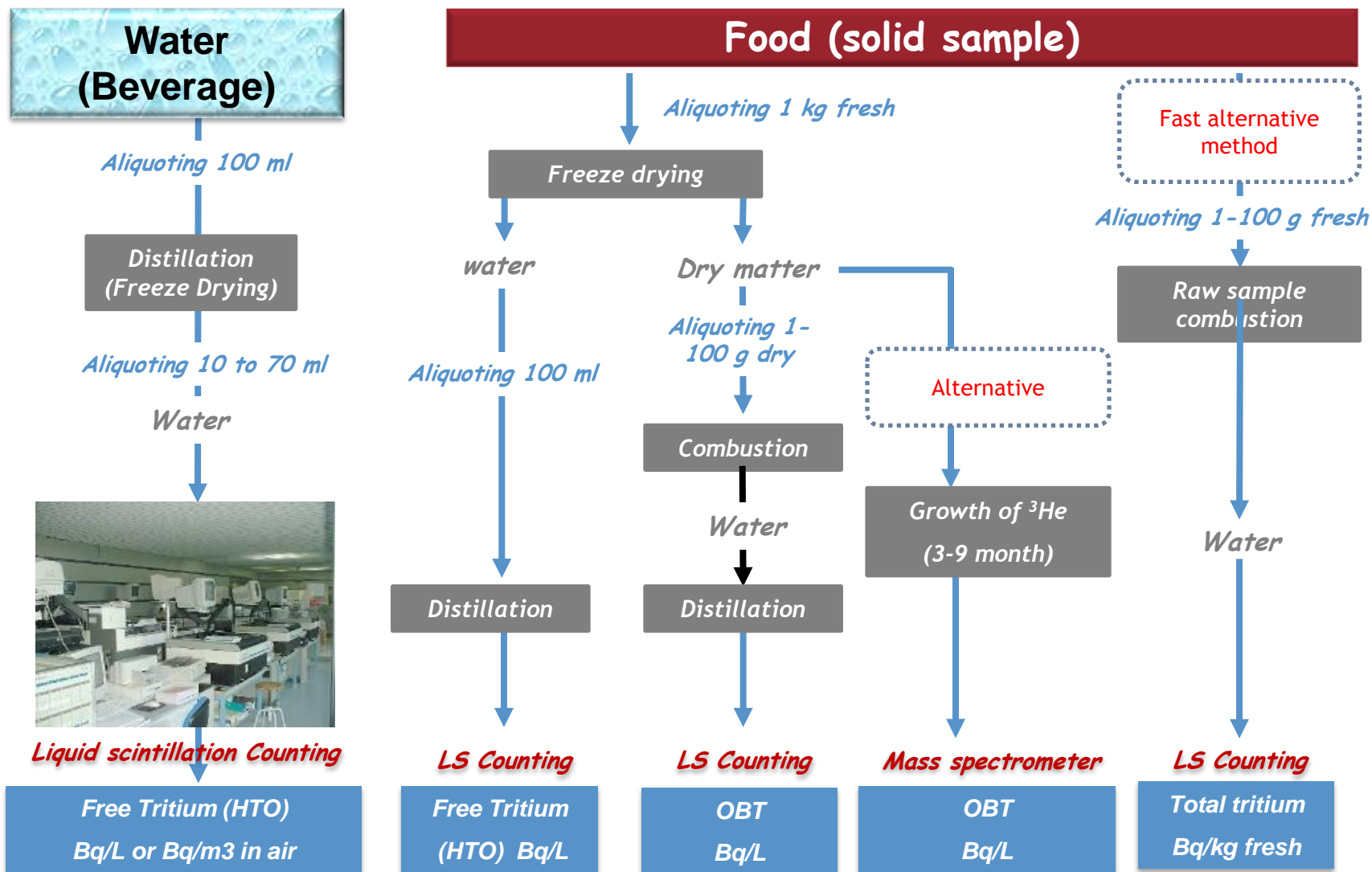
Scheme example for « gamma - organically bound ^3H – C – Sr, Pu Am U » analysis

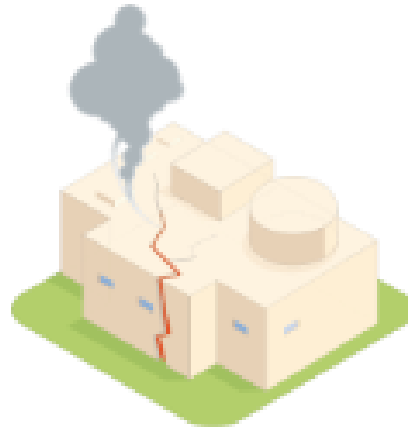


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³H

Key steps in analysis of tritium





What about emergency situation ?



OBJECTIVES OF EMERGENCY MONITORING

To provide accurate and, mostly, timely data on the level and degree of hazards resulting from a radiological emergency.

Assist decision makers :

- On the need to take protective actions, on the basis of Operational Intervention Levels (OILs);
 - To determine the extent and duration of the hazard;
 - To confirm the efficiency of remedial measures, such as decontamination procedures.
- Later (post accidental) : radionuclide concentrations in food, drinking water and other samples need to be quantified



Post accidental situation

The type of released radionuclides depends on the kind of radiological emergency.

In the case of the reactor accident, in some possible scenarios :

- Volatile radionuclides ^{131}I , ^{132}I , ^{133}I , ^{131}Te , ^{132}Te , ^{134}Cs , ^{137}Cs , ^{103}Ru and ^{106}Ru and noble gases have the highest probability for release.
- During the first days and weeks after an accident the highest portion of the dose comes from short lived radionuclides, like ^{132}I , ^{131}I , ^{132}Te , ^{103}Ru , ^{140}Ba and ^{141}Ce .
- ^{89}Sr , ^{90}Sr can be of first interest in the crisis management (emergency and post accidental).

In most of the case, the following radionuclides must be considered to monitor foodstuff :

	^3H	^{89}Sr	^{90}Sr	^{95}Nb	^{95}Zr	^{103}Ru	^{106}Ru	^{131}I	^{134}Cs	^{137}Cs	^{141}Ce	^{144}Ce	^{238}Pu	$^{239+240}\text{Pu}$	^{241}Am	^{242}Cm
Water																
Vegetable																
Milk																
Meat																
Other fodstuff																

Radionuclides mainly involved in the contamination of foodstuffs (UNSCEAR)



Post accidental situation

Particularly in emergency situation, sample coding and record keeping is of first importance. The recorded data must be sufficiently complete for the possible future uses that may be made of the final analytical results :

- where,
- when,
- what,
- how much...



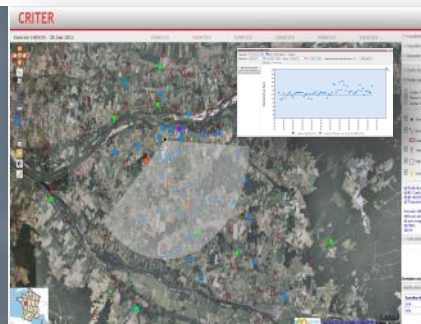
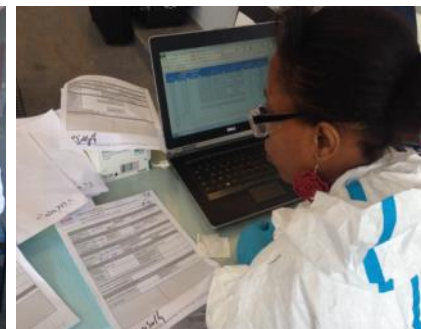
- Radioprotection must be the priority for the lab team.
- As far as possible you should preserve your capacity to realize some measurements of non contaminated samples (avoid cross-contamination between samples)



Post accidental situation

Lab training exercise

Every year, the IRSN's environmental laboratories perform an exercise simulating the massive arrival of potentially highly contaminated samples following a nuclear accident. This exercise, played in a temporary structure to preserve the technical platform dedicated to low-level measurements, allows to train the teams (speed of publishing results and radioprotection constraints especially) and to test the analytical chain (recording, processing and measurement of samples) in emergency situation (since 2017 with mobile Labs).





Post accidental situation

In an emergency, fast / easy analysis of sample are needed

γ spectrometry stays of first importance in emergency situation.

- ▶ The usual detectors can be used.
- ▶ It is vitally important to protect the shield and detector from contamination by the sample during counting.
- ▶ Many laboratories will bag the detector and inner shield with a replaceable large plastic garbage bag.
- ▶ If a spill occurs, or if the outside of a counting container is contaminated, it can be readily decontaminated and so the shield and detector remain uncontaminated.





Post accidental situation

γ screening can be done using easy small portable detector

In the event of an emergency numerous contamination checks must be carried out on foodstuffs. This important sample flow must be oriented rapidly by a sorting phase so as not to saturate the main human and material resources concerned (TSO laboratories, operator, academic or private).

It should be advantageous to be able to offer the local actors involved (local administrations, associations, private individuals, ...) easily measuring devices for the immediate determination of levels of contamination of food products.

These devices should offers :

- Robustness and easy maintenance
- Cheap
- Adapted to standardized counting geometries (Marinelli 1L, SG500, D380, etc ...)
- Capable of quantifying the main radionuclides (^{131}I , ^{134}Cs , ^{137}Cs) with performances in line with the thresholds defined by the current regulations (involving ideally configurable thresholds)
- Space-saving and portable
- Simple to use for a non-physicist (simple mode / expert mode for calibration)
- Ensuring a good traceability of the measured samples



Post accidental situation

Several models are available on the market allowing DL of about few 10 Bq/kg for ^{137}Cs - for a price ranging from few 1000\$ to 25000\$
 For example (not exhaustive !) :



Adini -RUG-91-2



APVL radeye



ATOMTEK AT1135



BERTHOLD LP200



Berkeley Nucleonics
Food-SSA



SARAD
Bioscout



SPEKTR
MIG -053



Eurorad
Bqmeter



GlobalAsia
Foodlight



Kromek
Food inspector



Mirion
Spir Quanta



Ortec
FoodGuard



Polimaster
PM1406



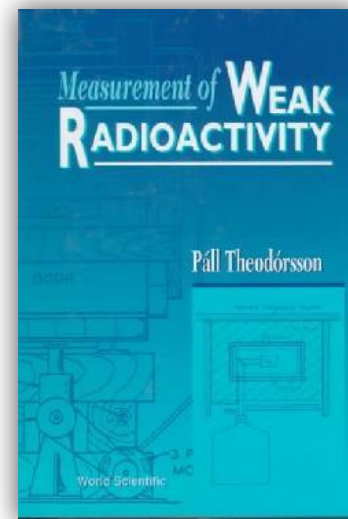
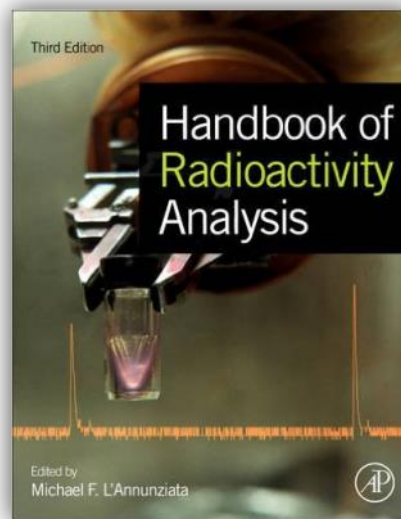
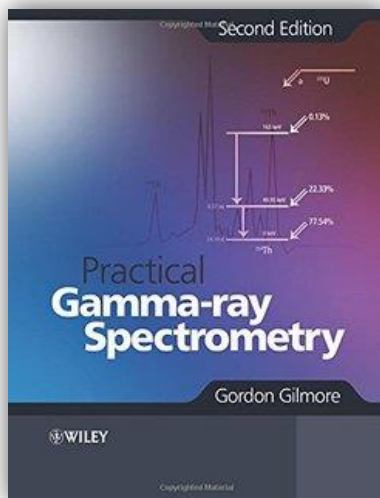
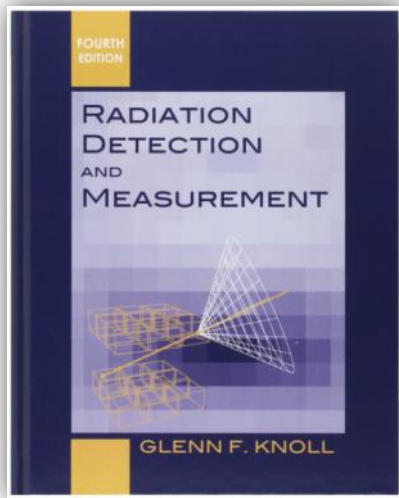
SEA
EL55

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- ❑ The EML Procedures Manual, HASL-300, is also a significant resource for scientists who collect samples, perform field measurements or analyse samples. The 28th edition, released in February 1997 is available on-line: <http://www.hsdl.org/?view&did=487142>.

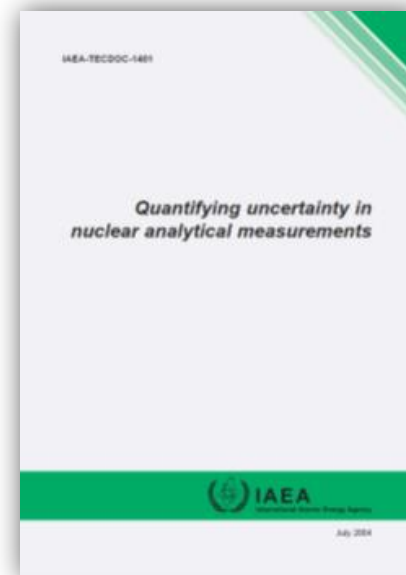
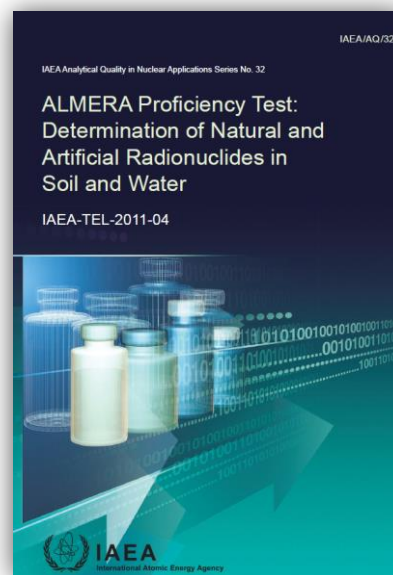
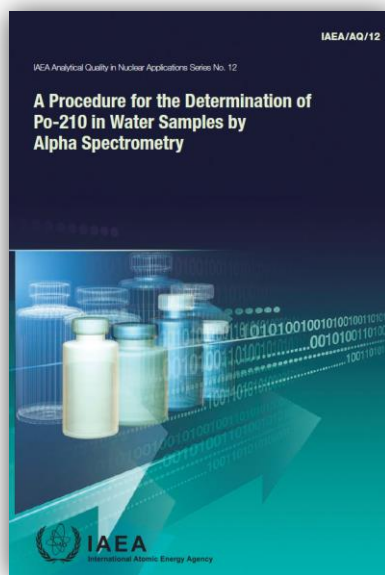
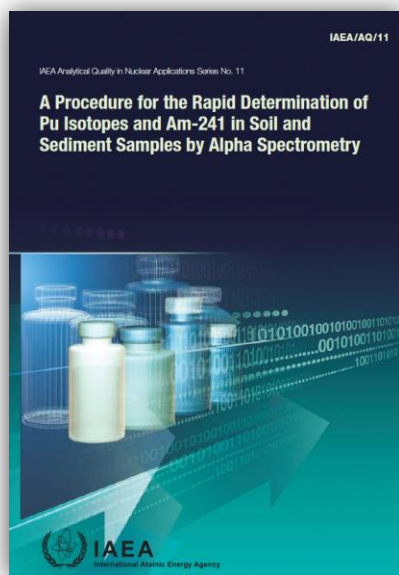


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Thanks you for attention



Any questions ?