# RADIOACTIVE IN WATER BODIES

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# MAJOR CAUSES OF POLLUTION IN WATER

- **SOIL EROSION**
- **UNTREATED SEWAGE**
- **INDUSTRIAL EFFLUENTS**


**A spill of hydraulic fluid from a truck can lead to environmental damage**

***1 litre of oil can spoil 100,000 litres of drinking water***

# HISTORY (Radiation & Radioactivity)

**1895** Roentgen: Discovery of X-ray

**1896** Becquerel: Discovery of Radioactivity

**1911** Discovery of Radium-226

**1912** Rutherford Experiment

**1913** Bohr Shell Model

**1928** Geiger and Muller: Developed G-M Counter

**1939** Hahn: Discovery of Nuclear Fission

**1945** Atomic bomb dropped on Japan

**1950's** Decades of atom bomb testing

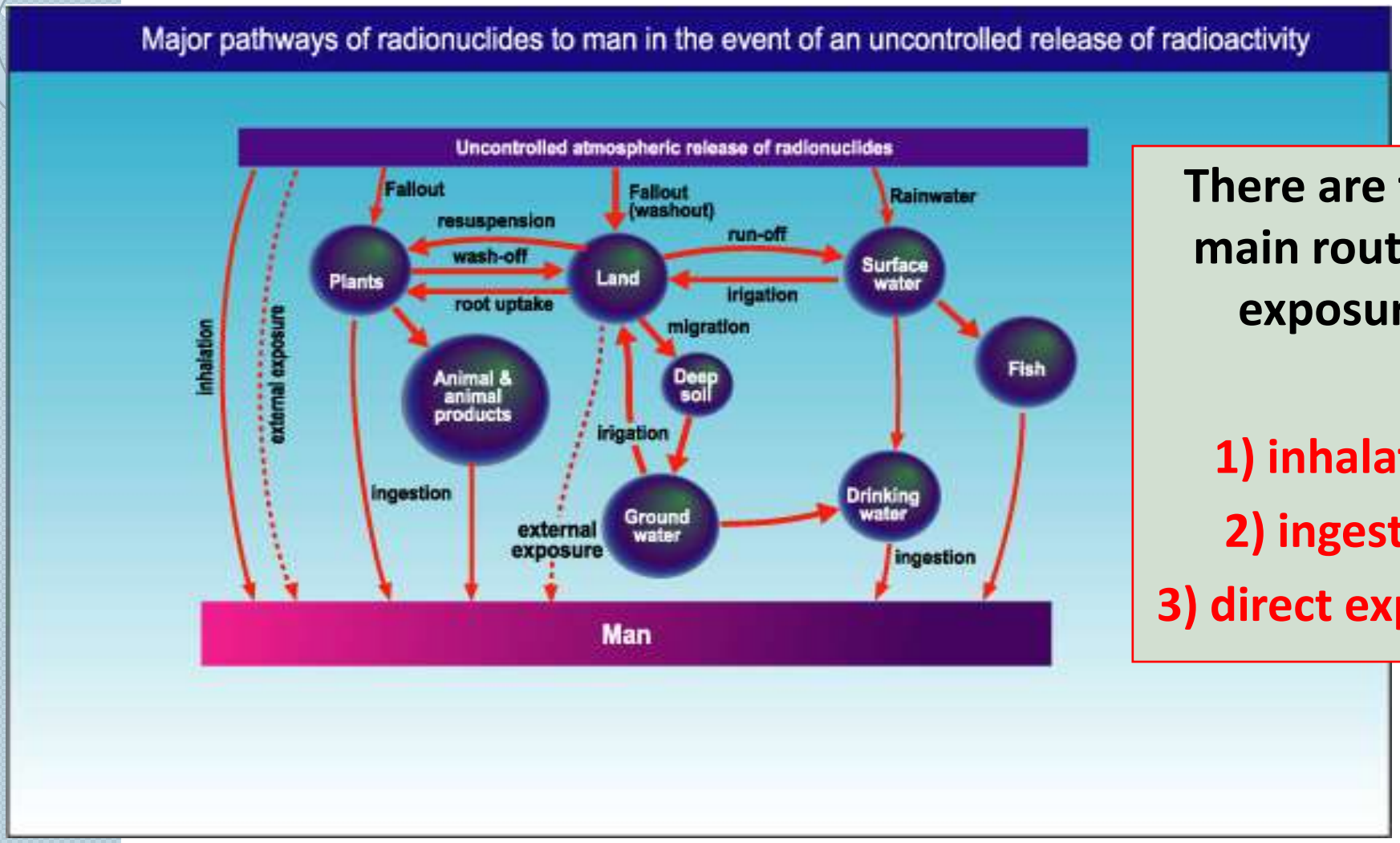
# HISTORY (CONTINUE)

| | |
|---|---|
| 1950's | Proportional counter was developed |
| Mid 1950's | First nuclear power station |
| Late 1950's | Scintillation counter became popular |
| 1957 | Fire on nuclear reactor – Windscale |
| 1979 | Nuclear reactor accident at Three Mile Island, Pennsylvania, U.S. (INES Level 5) |
| 1986 | Nuclear reactor accident at Chernobyl, Russia (INES Level 7) |
| 2011 | Nuclear reactor accident at Fukushima, Japan (INES Level 7) |

# What is radioactivity?

- Radioactivity – term used to describe disintegration of atoms
- Atom can be characterized by the number of protons in the nucleus
- Some natural elements are unstable – their nuclei disintegrate or decay – releasing energy in the form of radiation
- This physical phenomenon is called radioactivity

# Pathways of radionuclides into human body



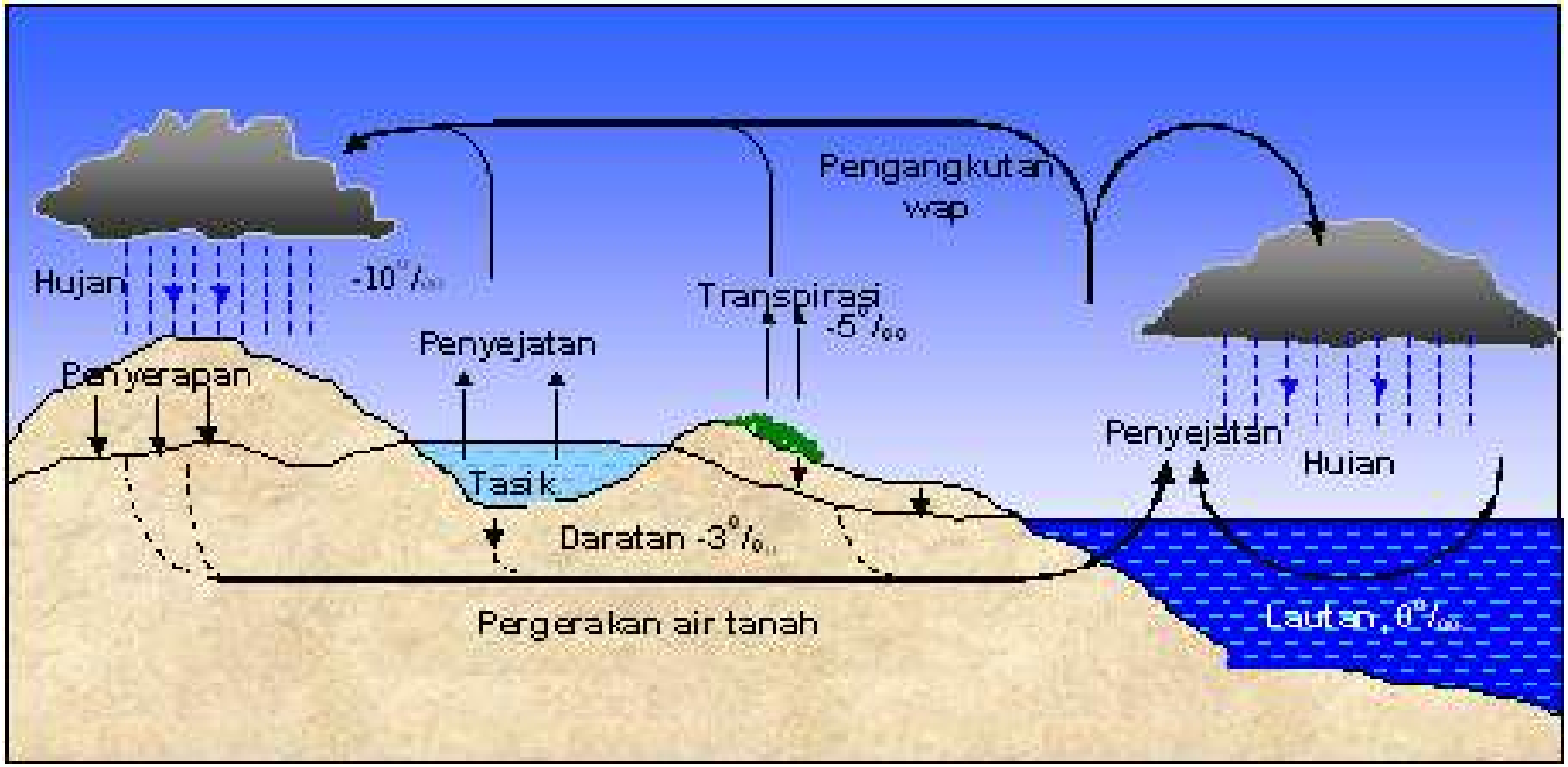

There are three main routes of exposure :

1) inhalation

2) ingestion

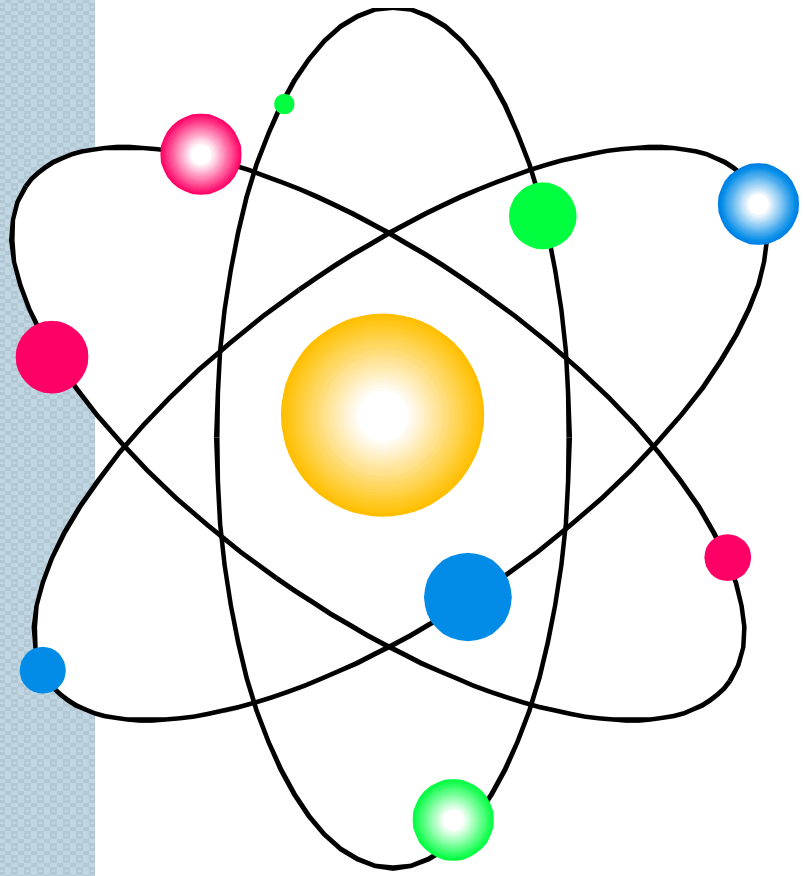
3) direct exposure

# Water sources & pollution




Kitaran hidrologi

# RADIOACTIVITY IN ENVIRONMENT



- COSMOGENIC
- PRIMORDIAL
- MAN-MADE

# ‘Cosmogenic’ Radionuclide

**Resulting from the reaction of cosmic rays with the elements in the air (mainly by neutron capture)**

**Example: H-3, Be-7, C-14, Na-22, etc.**

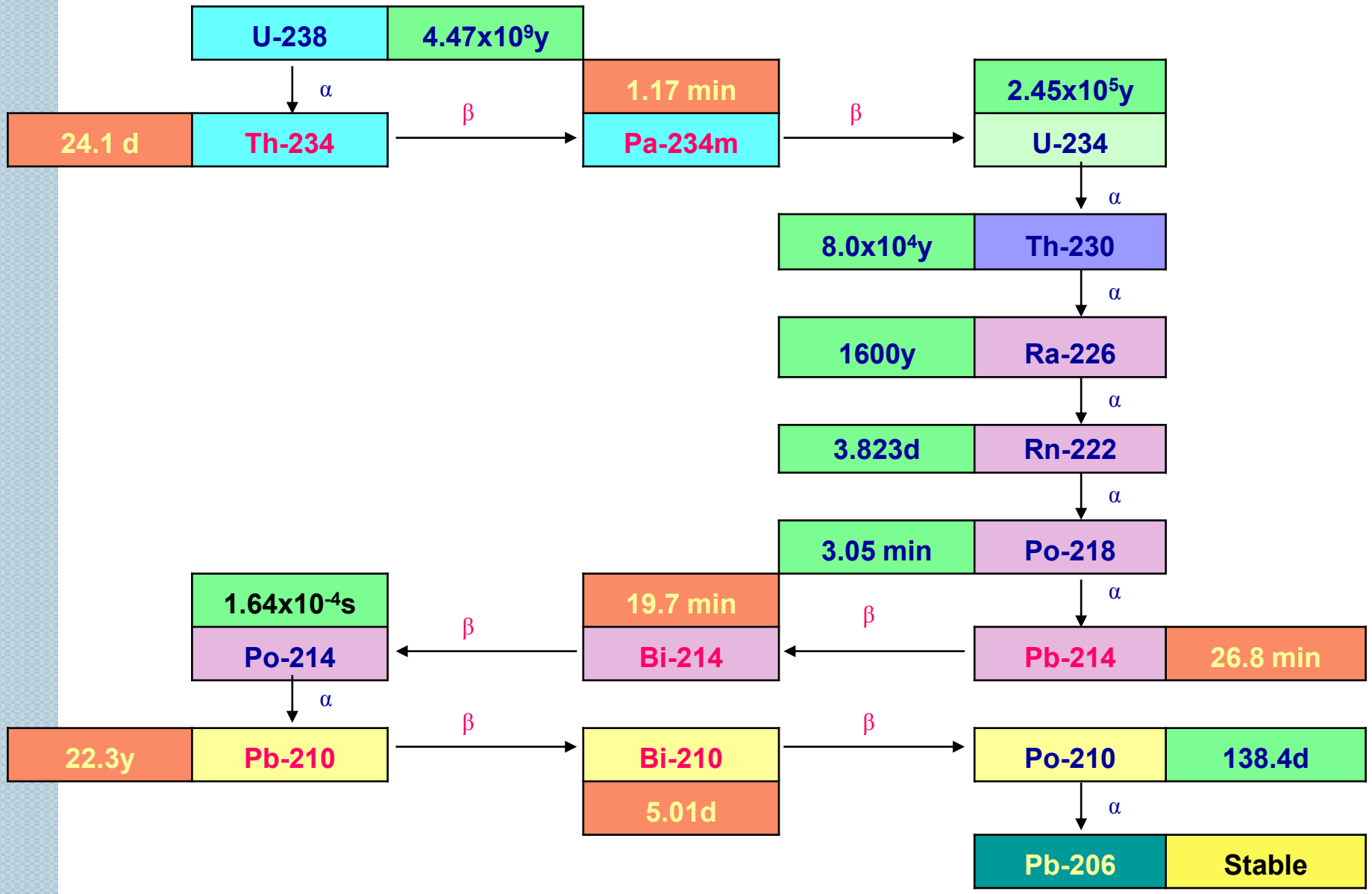
$$^{14}N + n \longrightarrow {}^{3}H + {}^{12}C$$

$$^{14}N + n \longrightarrow {}^{14}C + {}^{1}H$$

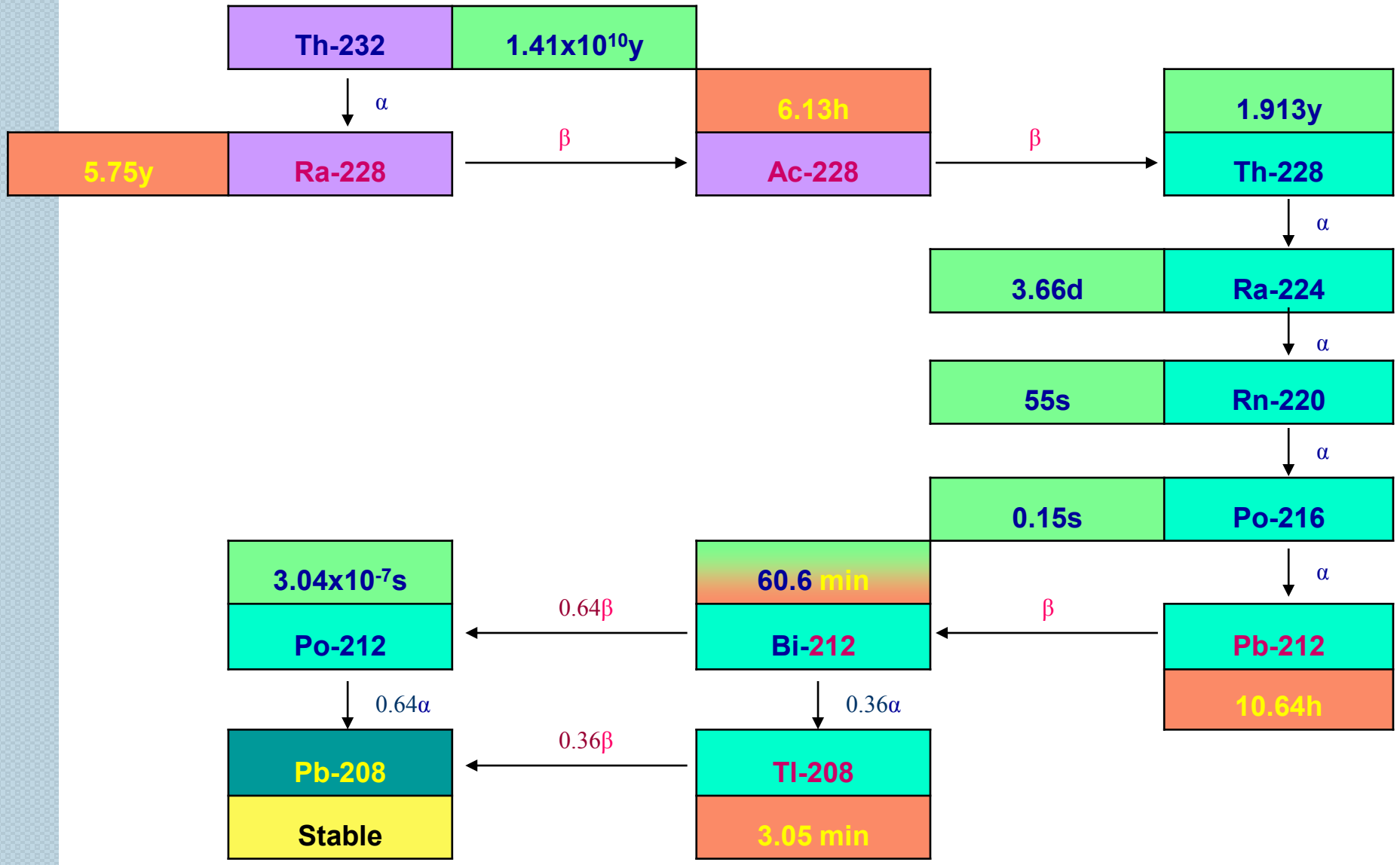
# ‘Primordial’ Radionuclide

- Radionuclides that have very long half- life, the age equaled the world.
- Example: K-40, uranium and thorium series.

# Uranium-238 Series



# Thorium-232 Series



# ‘Man-Made’ Radionuclide

- Technologically enhanced natural radioactivities
- Nuclear power plants
- Medical radioactivity
- Disposal of nuclear waste
- Use of radionuclides in industries for various applications
- Nuclear tests

# Technologically enhanced natural radioactivities

a. Mining and milling operation
   - Uranium, thorium and their daughter nuclides
   - Mining of phosphate rock – for use as fertilizer

b. Enhanced concentration of Rn, Th and their daughter nuclides
   - Use of Rn-rich water
   - Release from building materials
   - Dwellings constructed on Ra-rich soil or mill tailing

c. Caves, hot springs and geothermal energy production

d. Combustion of coal
   - C-14, U-series, Th-series, K-40

# Nuclear Power Plants

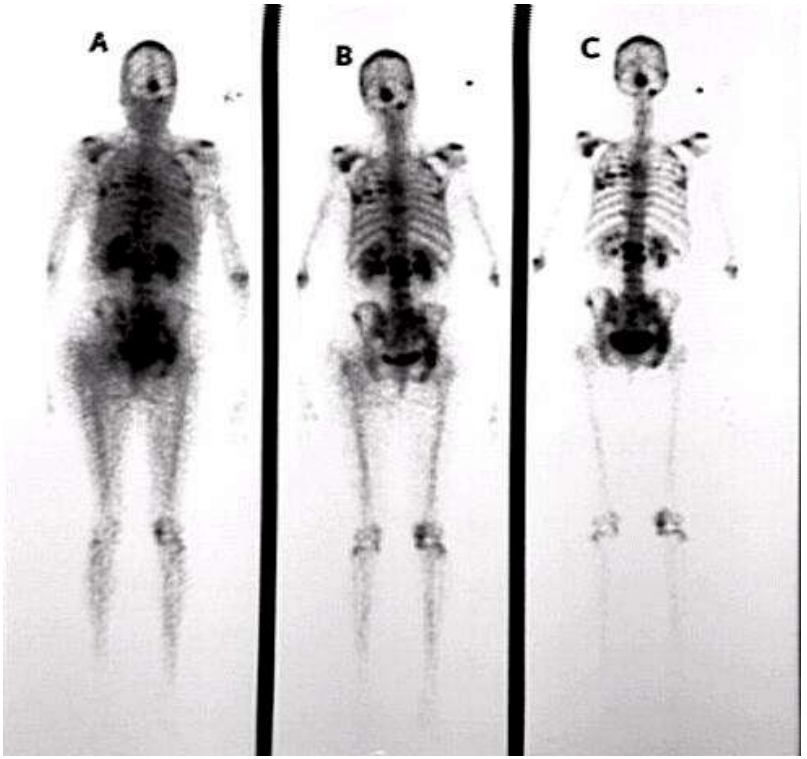
- Nuclear power plants under current standards produce little radioactive pollution due to safety precautions that must be adhered to.
- Accidents at these power plants can cause dangerously high radioactive pollution.

# Medical radioactivity

Diagnostic uses of radiopharmaceuticals

i.e. I-131, Au-198, Co-58, Hg-197, Sr-85, Hg-203, Tc-99m, I-132, Co-57, Xe-133

# Diagnostics- Nuclear Medicine




- Inject chemical compound labeled with suitable radioisotope into body
- Radioisotope accumulates in specific organ
- radiation emitted is detected and image is produced using computer software

  e.g. $^{99m}$Tc-pertechnetate pyrophosphate for bone scanning

# What is Radioactive Pollution?

- Addition of radiation to environment by using radioactive elements
- Release of something unwanted into the environment and, in this case, the unwanted thing is radioactive material
- Radioactive contamination, is the deposition of, or presence of radioactive substances on surface or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable
- Such contamination presents a hazard because of the radioactive decay of the contaminants, which emit harmful ionizing radiation such as alpha or beta particles, gamma rays or neutrons.

# TYPE of POLLUTION

- **Continuous Pollution**: This type of condition exists in uranium mines, nuclear reactors, test labs, etc. where the humans are under continuous exposure to radioactive contaminants and protective clothing is required to avoid radiation exposure.
- **Accidental Pollution**: This type of condition exists during accidental exposure to radiations by virtue of equipment failure, radiation leak, faulty protective equipment, etc.
- **Occasional Pollution**: This condition exists during isolated experiment or test of nuclear substance.

# EFFECTS on HUMAN BEINGS

- Can vary from mild to fatal: the magnitude of the adverse effects largely depends on the level and duration of exposure to radioactivity. Low levels of localized exposure may only have a superficial effect and cause mild skin irritation.
- Long-term exposure or exposure to high amounts of radiation can have far more serious health effects. Radioactive rays can cause irreparable damage to DNA molecules and can lead to a life-threatening condition.

# EFFECTS on HUMAN BEINGS (cont.)

- The rapidly growing/dividing cells, like those of the skin, bone narrow, are more sensitive towards radioactive emissions.
- On the other hand, cells that do not undergo rapid cell division, such as bone cells and nervous cells, aren't damaged so easily.
- Skin cancer, lung cancer and thyroid cancer are some of the common types of cancers caused by radiation effect.

# What are radionuclides health effects?

| Contaminant | Health Effect |
|---|---|
| Combined radium-226/-228 | Some people who drink water containing radium 226 or radium 228 in excess of the maximum contaminant level (MCL) over many years may have an increased risk of getting cancer. |
| Gross Alpha | Some people who drink water containing alpha emitters in excess of the MCL over many years may have an increased risk of getting cancer. |
| Beta Particle and Photon Radioactivity | Some people who drink water containing beta particles and photon emitters in excess of the MCL over many years may have an increased risk of getting cancer. |
| Uranium | Exposure to uranium in drinking water may result in toxic effects to the kidney. Some people who drink water containing alpha emitters, such as uranium, in excess of the MCL over many years may have an increased risk of getting cancer. |

# *RADIOACTIVITY MEASUREMENT TECHNIQUES*

# Analysis Techniques

- Considerations for sample preparation and measurement:
  - Radionuclides
  - Chemical forms
  - Physical characteristics
  - Interfering radionuclides
  - Sensitivity
- Preliminary information and/or screening
  - Identify α, β, or γ emissions

# Radiochemistry

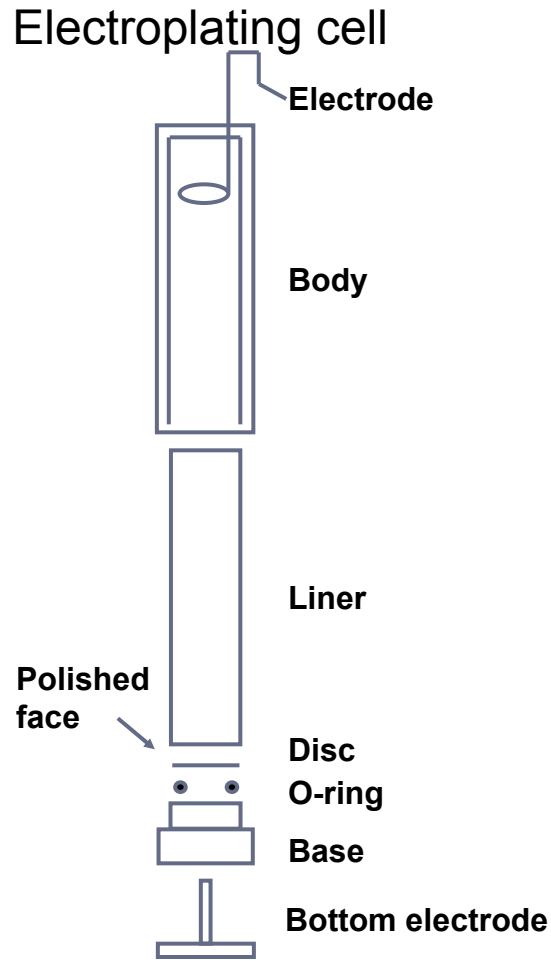
- α and β emitters usually separated from:
  - Bulk of the sample matrix
  - Interfering radionuclides
- Separation generally involves:
  - Sample preparation and preconcentration,
  - Chemical separation of the radionuclides,
  - Preparation of the source for counting.
- Little preparation for pure emitters in a simple matrix (e.g. $^{3}H$ or $^{14}C$ in urine)

# Radiochemical separation

- Dissolution of precipitate
- Chemical separation by;
  - Solvent extraction ($\Rightarrow$ organic phase),
  - Ion exchange separation (e.g., column),
  - Co-precipitation (addition of stable carrier)

# Preparation of source for counting

- γ and X-ray: normally none or minimal
- β emitters: precipitation of anions, filter or planchette
- α emitters: electrodeposition (SS disc), co-precipitation (filter), solvent extraction



# COUNTING SYSTEM FOR α, β AND γ

| COUNTING SYSTEM | DETECTOR | RADIATION DETECTED | ENERGY RANGE |
|---|---|---|---|
| Low Background α/β Counting System | Gas Proportional | α, β | 0.2 – 5.0 MeV |
| Liquid Scintillation Counting System | Photomultiplier Tube (PMT) | β (low energy) | 0 – 2000 keV |
| Gamma Spectrometry Counting System | Hyperpure Germanium | γ | 50 – 2000 keV |
| Low Energy Photon Spectrometry Counting System (LEPS) | Hyperpure Germanium Si(Li) X-ray | x-ray, γ (low energy) | 3 – 400 keV 1 – 30 keV |
| Alpha Spectrometry Counting System | Silicon Surface Barrier | α | 3 – 8 MeV |

Gamma Spec

Gross Alpha/Beta

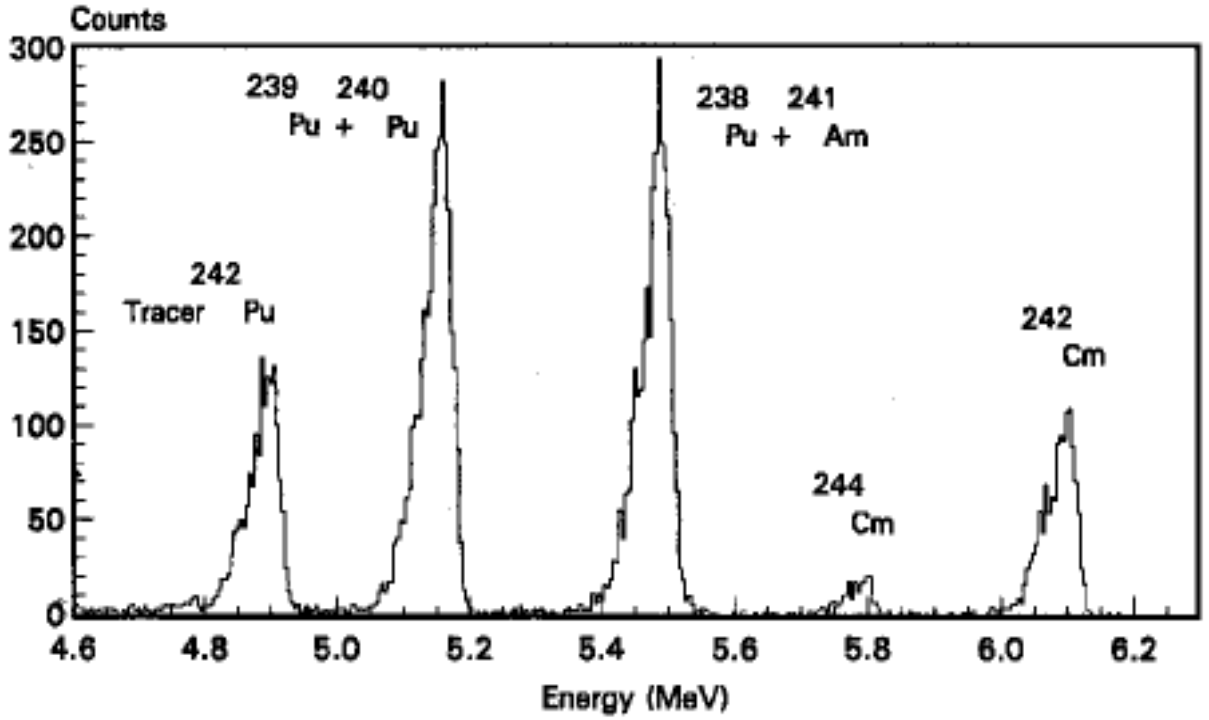
Alpha Spec

Liq. Scint. Counter

# Detection methods - α counting

- Gross α: gas flow proportional, scintillation (ZnS), counting efficiency ≈ 45%
- LSC (higher activity levels)
- Nuclide specific: α spectrometry, Si detectors in vacuum chambers (very long counting time for mBq activities)

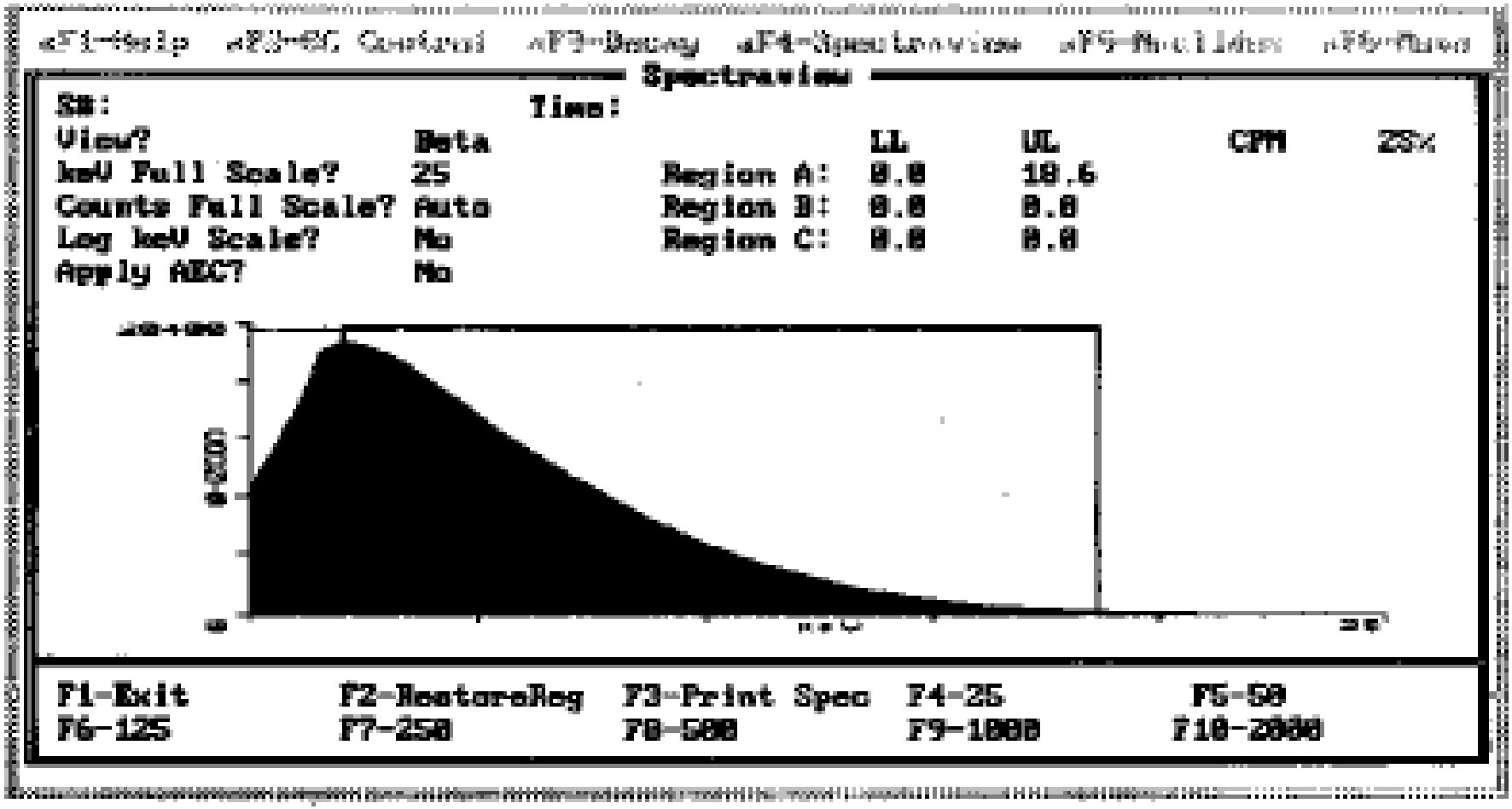
# Detection methods - α spectrum



# Detection methods - β counting

- LSC, esp. for low energy β emitters ($^{3}H$, $^{14}C$, $^{241}Pu$, etc.)
  - Dispersion in organic liquid scintillator, light photons, PM tubes
  - Quenching effect (interference, absorption)
  - Energy discrimination is limited (low, medium and high energy regions)
  - Background from $^{40}K$ is a problem
- Gas flow, GM, proportional counters for energies > 100 keV

# Detection methods - β spectrum (LSC)



# Detection methods - γ counting

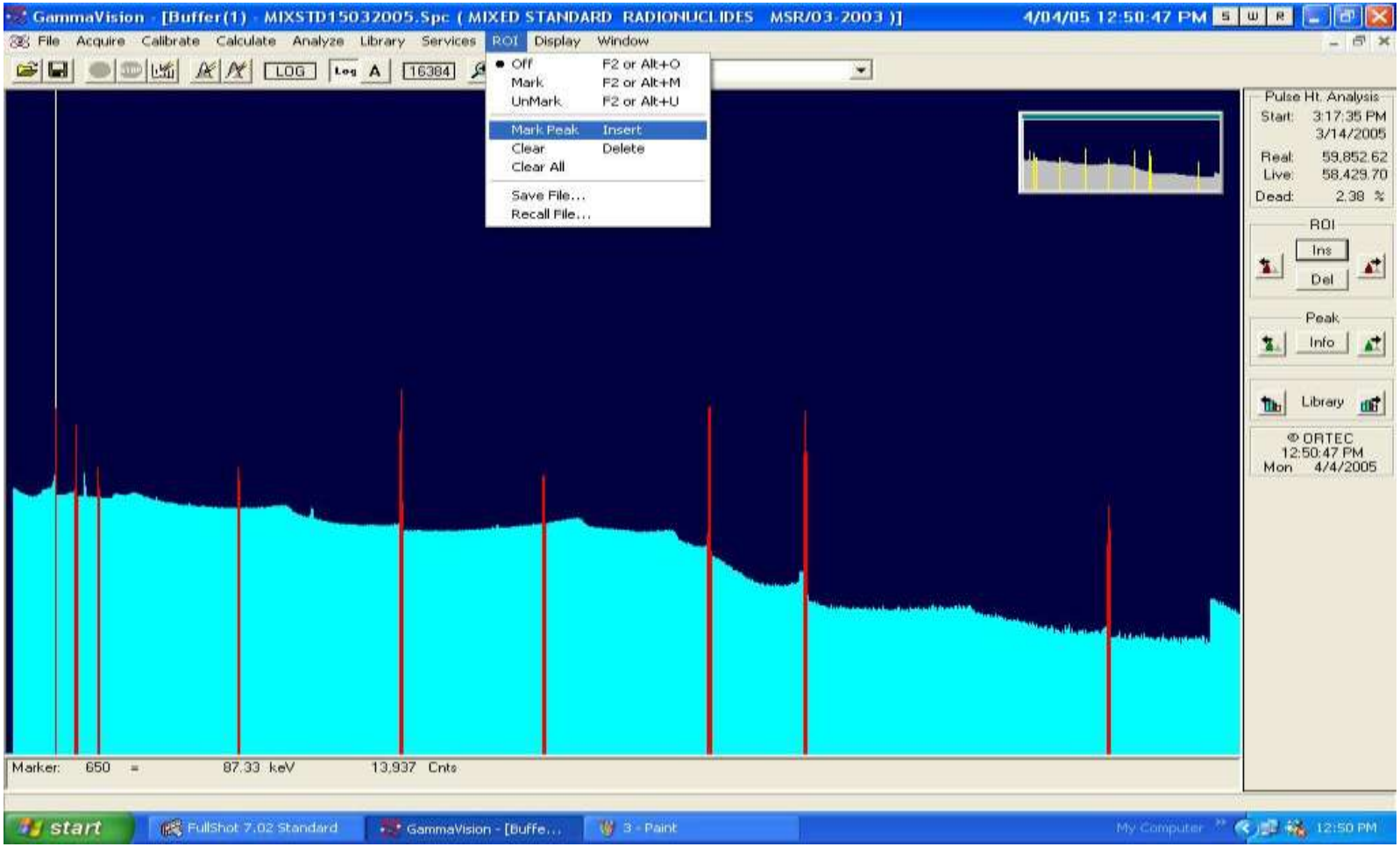
- Counting in bulk samples (for ≈ keV energies attenuation will be significant)
- Primarily HPGe or NaI(Tl)
- Low background shielding is crucial (natural γ emitting radionuclides)

# Detection methods - Photon counting

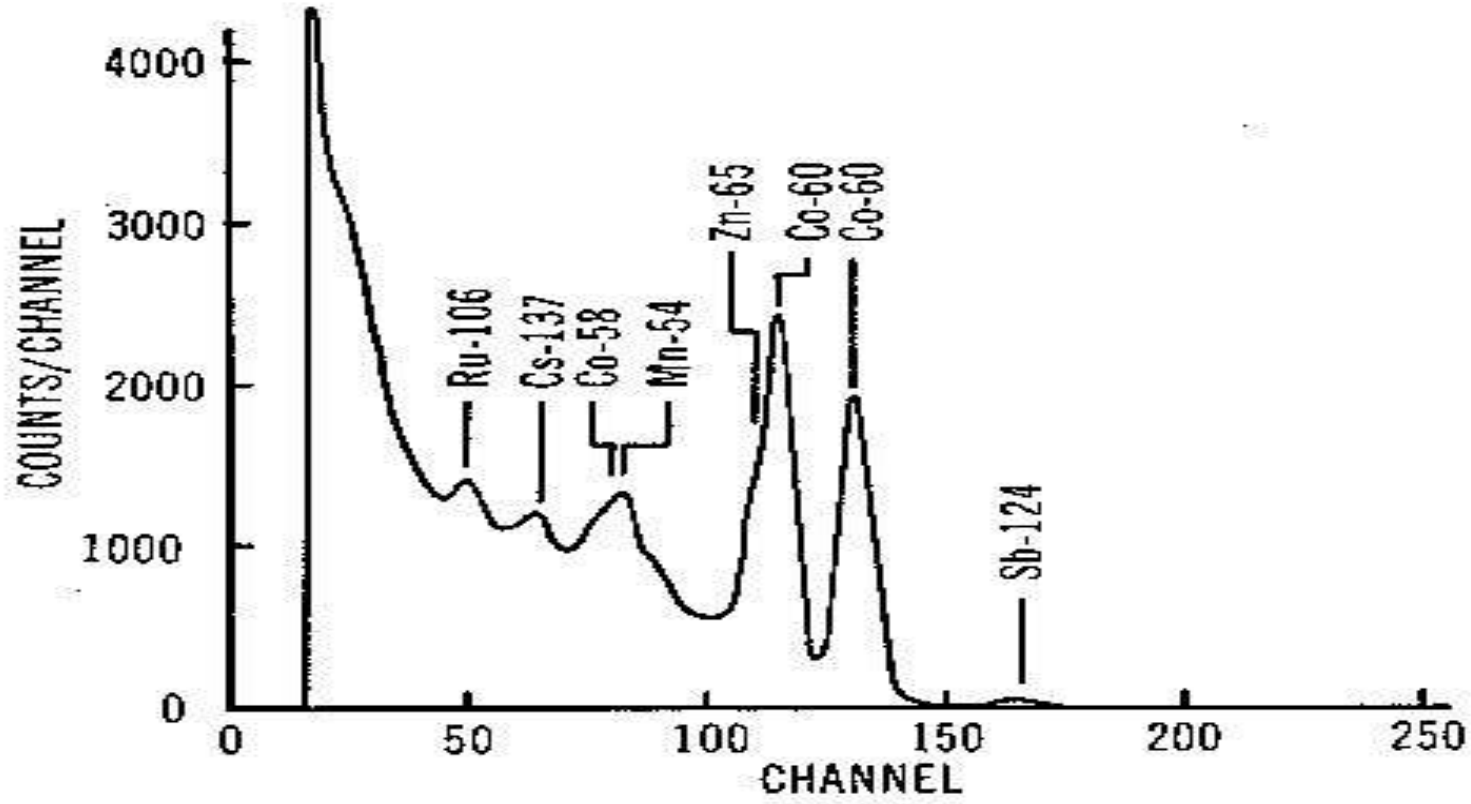
γ spectrometry:

- Fast (preparation and measurement)
- Sensitive
- Equipment rather expensive
- Analytical work can be shared with environmental monitoring

# Detection methods - HPGe γ spectrum



# Detection methods - NaI(Tl) γ spectrum



# GROSS $\alpha$ and GROSS $\beta$ ACTIVITY MEASUREMENT IN WATER

- **Gross Alpha – Combination of alpha radiation emitted by alpha radionuclide in sample**

  **E.g.: U-238, Th-232, etc.**

- **Gross Beta – Combination of beta radiation emitted by alpha radionuclide in sample**

  **E.g.: K-40, Sr-90, etc.**

# GROSS α and GROSS β ACTIVITY MEASUREMENT

- semi-quantitative technique for measuring overall radioactivity in samples without a great deal of sample preparation.
- to measuring levels of activity for screening purpose in sample such as water, soil and air.
- to produce quantitative results for specific radionuclides
  - ~ more sophisticated wet chemical separation and preparation
  - ~ i.e. Sr-89 / Sr90 and Ra-226.

Gross Alpha / Beta Counting has the advantage that it is sensitive to a wide range radionuclides, but does not inherently provide any reliable information about the identity of the radioactive isotopes present.

# LOW BACKGROUND ALPHA/BETA COUNTING SYSTEM

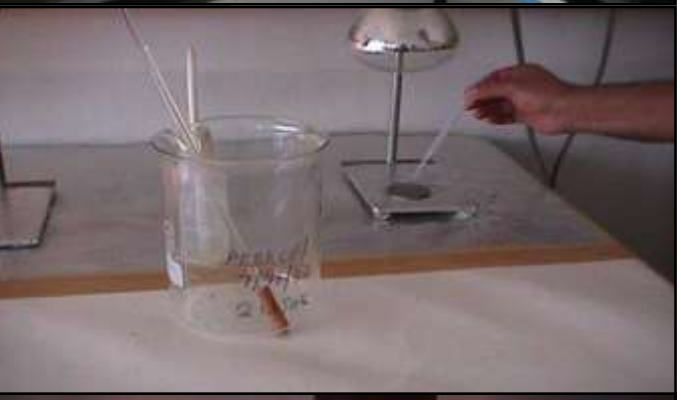
Instrument "*The low background alpha/beta counting system*" include:

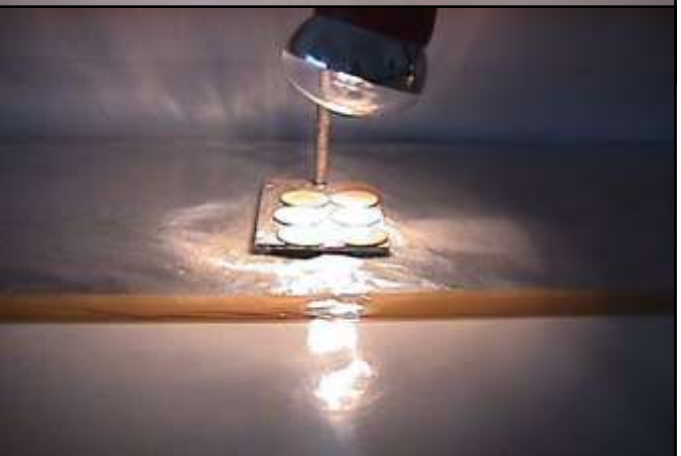
- "*gas flow proportional detector with a thin windows*"
- *P-10* gas *[Argon (90%),Metana (10%)]*
- sample changer (50 samples)
- standard PC
- Eclipse Software (Canberra)

# Type of Sample

- Sample – (i) Drinking Water
  (ii) Food
  (iii) Environmental sample
    - Water
    - Sludge
    - Soil
    - Sand
    - Sediment
    - Air particles (aerosol)
    - Flora and Fauna (vegetation)
  (iv) Water Filter System, etc


# Flowchart of Radioactivity Analysis for Gross Alpha and Beta in Drinking Water, Mineral Water, etc.





Sample

↓

Registration

↓

Preparation
*Step 1*: Evaporating the water sample (2L) to near dryness (until 10 ml or less) on a hot plate

↓

*Step 2*: Transfer the sample into planchette and dry to dryness under IR lamp

↓

Counting
Using Low Background Alpha/Beta Counting System

↓

Data Interpretation

↓

Analysis Result Issuance

# Interference

- Moisture obstructs counting and self-absorption characteristic

- Non-uniformity of the sample residue in planchet
  - accuracy
  - precision

# FOOD ACT 1983 AND FOOD REGULATION 1985

The Malaysian Food Act 281 (1983) on drinking water quality requires license from Ministry of Health (MOH) for all locally produced and imported bottled mineral and drinking water before being sold to the public.

Companies are required to have their drinking water products analyzed for physical, chemicals, bacteriology and **radiological (gross alpha/gross beta analysis)** parameters before a license is given to produce and market the product. The radioactivity levels in drinking water are regularly monitored by MOH and companies are required to send their samples to **Radiochemistry and Environment Laboratory (RAS), Malaysian Nuclear Agency**. RAS laboratory has been providing radioactivity analytical services for gross alpha and gross beta in water samples since 1990 and has been appointed as the official laboratory by MOH for the radiological parameters.

# STANDARD FOR DRINKING AND MINERAL WATER

**(PERATURAN 394 (AIS), 360 A (AMS), 360B(AMB) DAN 360C (AIR DARI MESIN JUAL AIR)**
**PERATURAN- PERATURAN MAKANAN (PINDAAN) 1991**
**AKTA MAKANAN 1983**

1. **CHEMICAL**
2. **BACTERIOLOGICAL**
3. **RADIOACTIVITY**

***Maximum permissible limit (Bq/l)***

| | |
|---|---|
| ***Gross $\alpha$*** | ***0.1*** |
| ***Gross $\beta$*** | ***1.0*** |

# Thank You