Seminar 2

Radiation Protection in Norm Industries

Introduction

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- Definitions, radionuclides of interest
- Industries associated with Norm
- Relevant pathways
- Briefly description of the regulatory approach

General remarks

- Nearly all materials contain trace amounts of natural radionuclides.
- When these materials are processed: concentration or enhancement of the levels of these radionuclides.
- Enhancement: when human activity alters these naturally occurring radioactive material in its composition, concentration, availability to people.
- Some non nuclear industries concentrate in its processes natural radionuclides present with other minerals.
- By-products, wastes and the final products from processes may enhance the exposure to workers and members of the public.

Definitions (1)

NORM: *Naturally Occurring Radioactive Materials*

Radioactive elements of natural origin that are ubiquitous in our environment.

Long-lived radioactive elements of interest include uranium, thorium and potassium, and any of their radioactive decay products, such as radium and radon.

These elements have always been present in the earth's crust.

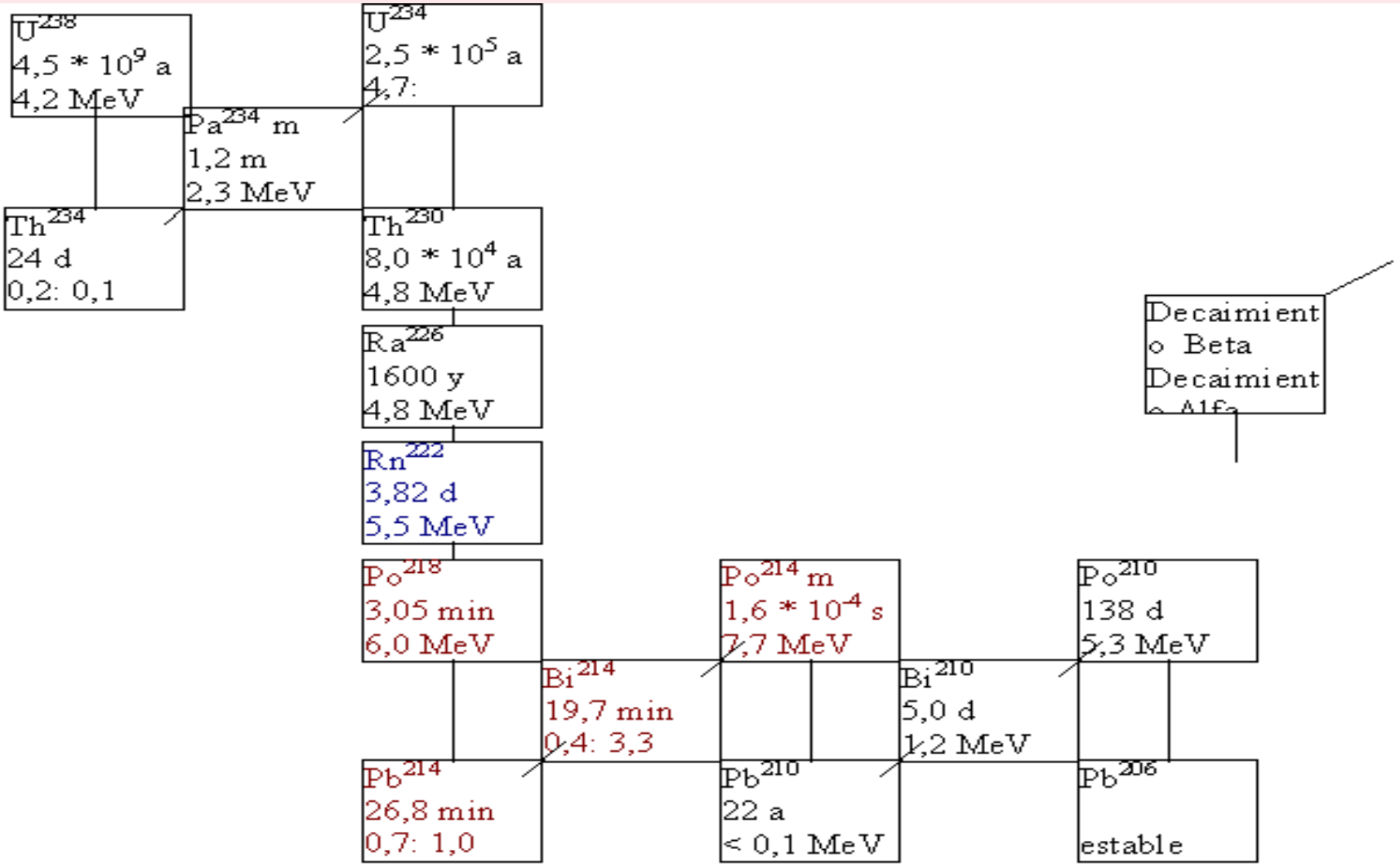
Definitions (2)

TENORM: *Technologically Enhanced Naturally Occurring Radioactive Material*

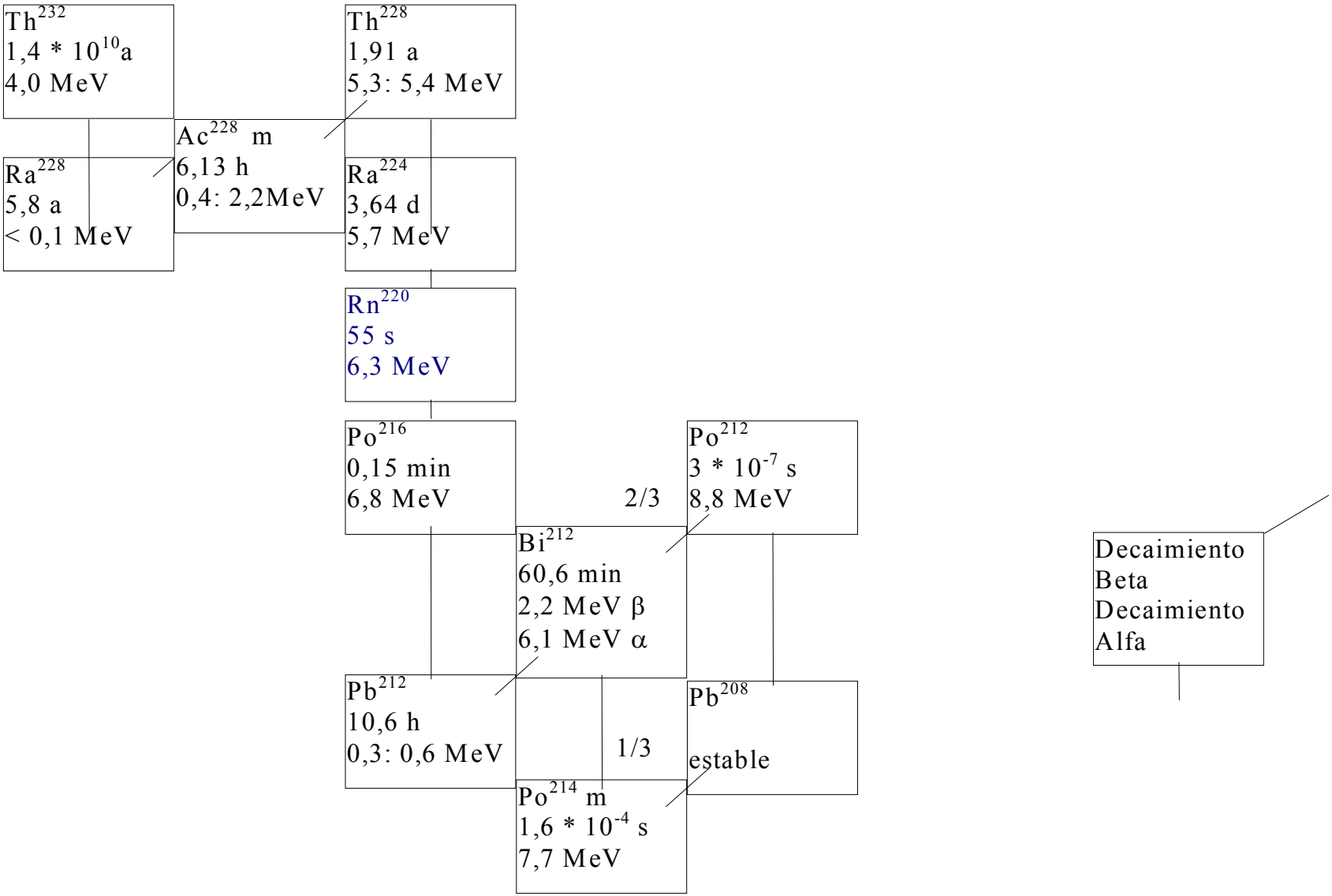
Materials of concern: where radionuclides have become concentrated as a result of an industrial process.

But, also minerals with unenhanced natural radionuclides activity concentration.

No distinction between both for purposes of radiation protection → NORM



Esquema de decaimiento del U-238



Esquema de decaimiento del torio

Industries associated with Norm

- Extraction of rare earth elements;
- Production and use of thorium and its compounds;
- Production of niobium and ferro-niobium;
- Mining of ores other than uranium ore;
- Production of oil and gas;
- Manufacture of titanium dioxide pigments;
- The phosphate industry;
- Zircon sands and refractory materials;
- Production of tin, copper, aluminium, iron and steel, zinc and lead;
- Combustion of coal;
- Water treatment.

Industries: types of materials

- Mineral ores

  Can contain activity concentration of several Bq/g. Very large quantities of material.

- By products and residues

  Processing may concentrate the radionuclides in them. May be by mass separation or physical (volatilisation) or chemical reactions (pptations) Concentrations may be high (several hundreds) but quantities smaller than the ores.

- Products

  The intentionally contain of thorium, but not for its radiological properties. Activity concentration may be high.

Combustion of coal

- Fossil fuels such as coal, lignite contain varying amounts of natural radioactivity depending on the area they are mined or extracted.
- When burnt the radioactivity is transferred to the ash with certain volatile radionuclides ^{210}Po and ^{210}Pb.
- The application of coal ash in building materials is regarded as the most significant from the radiological point of view:

  - it may affect indoor dose from external radiation and inhalation of radon decay products.

Oil and gas industry

Norm are typically located in subsurface formations created in the Jurassic period.

✓ The techniques used in forcing the oil to the surface includes recirculation of produced water, which is co-extracted with the final products.

- NORM are transported to the surface with this water.
- Pressure and temperature decrease results in the sulfate and carbonate precipitation in pipelines and internal surfaces of the equipments.

- ✓ Similar chemical behavior between radium and barium → co-precipitating of both elements.
- ✓ It can also be found other products of the uranium and thorium decay chains. (^{228}Th, ^{228}Ra, ^{226}Ra, ^{210}Pb)
- ✓ There is very large variability in radionuclide concentrations in sludges and scales from different wells because of the differences in the nature of the reservoirs.
- ✓ Other radionuclides of interest (**gas industry**)
  - radon gas
  - ^{210}Pb: usually forms a thin cap in the internal surface of processing equipments.

Metal processing

- ✓ The basic process by which metals and alloys are produced from metal rich ores is smelting.
- ✓ The specific activities of natural radionuclides in raw materials vary depending on their area of origin.
- ✓ Slags, dross, fly ash, furnace coal ash and scales may be produced as a result of the smelting process.
- ✓ The metal processing involving high temperatures is a potential source of emissions of ^{210}Po and ^{210}Pb to air.
- ✓ The main sources for emissions and residues are the installations for production of sinters and pellets.

Tantalum and niobium

- ✓ Tantalum is a refractory metal, good conductor of heat and electricity.
- ✓ Niobium is used on a large scale in all kinds of electronic equipment, nuclear reactors and aerospace.
- ✓ The minerals in niobium ores contain enhanced levels of the decay chains of ^{238}U and ^{232}Th.
- ✓ Tantalum occurs in combination with niobium and usually with tin, iron, manganese and rare earths.
- ✓ The ore is processed by melting, dissolution with strong acids, reduction to metalic niobium at 800^0C and a liquid-liquid extraction for removal of impurities.
- ✓ Because of the thermic process it may involve discharges into the air of ^{210}Pb and ^{210}Po.

Phosphate industry

- Divided into: mining and milling of phosphate ore and manufacture of phosphate products.
- The second one:

  - by thermal process: + silica + 1500^{0}C > phosphorus > H_3PO_4.
  - by wet process : + H_2SO_4 > H_3PO_4 + phosphogypsium
  - to produce fertilisers: H_3PO_4 + NH_3

- The Uranium of the ore is retained in the slag.
- Thermal process: ^{210}Po and ^{210}Pb are emitted.
- Radium follows the phosphogypsum path.
- It is usually disposed into open air piles or discharged into rivers or estuaries, giving rise to a local radioactive impact.

Titanium oxide pigment production

- Titanium oxide pigment is produced from the ores rutile (TiO_2) and ilmenite ($TiO_2 \cdot FeO$).
- A sulphuric acid process (dried, ground and heat)
  - Titanium sulphates are recovered and reduced.
  - The solution is concentrated, and a precipitation follows with removal of impurities.
  - The precipitate is calcinated at 1000°C to form the TiO_2 crystals.
- A cleaner chloride process
  - At 1000°C to form a mixture of chlorides ($TiCl_4$).
  - Condensation steps.
  - Purification and oxidation of the $TiCl_4$ to TiO_2.

Radioactivity from the ore appears in the liquid effluent and solid wastes.

Zirconium process

- Main uses: ceramics, refractories, chemicals, abrasives, additive in special types of glass.
- All zircon contains uranium and thorium.
- Milling: crushing, grinding and sizing, followed by a combination of magnetic and electrostatic separators.
- Zirconium smelting: heated to extract zirconium.
- External exposure:
  - raw material storage
  - and materials handling
- Inhalation exposure :
  - mixing and blending
  - firing of products.
- Ceramics and brick factories: bricks and roofing tiles. The firing temperature is 1200°C > the ^{210}Po is volatilised.

Rare earth process

- ✓ Mining, milling and chemical processing: extraction of the rare earth elements and compounds (alkali digestion of monazite and selective acid extraction of rare earths).
- ✓ Monazite concentrate: ^{232}Th and progeny.
- ✓ Mineral processing: especially dry milling gives rise to dust which contains radioactive particles.
- ✓ Radium is co precipitated in extraction processes.
- ✓ Chemical processing:
  - external exposure
  - internal exposure
    - * inhalation of airborne long lived activity due to thorium
    - * short lived activity due to thoron and daughter products

Production and use of thorium

- The most important application is the manufacture and use of thoriated electrodes for tungsten inert gas welding (TIG) followed by lighting, thorium is used to coat tungsten electrodes, gas mantles.
- Thorium is recovered commercially from the mineral monazite.
- Thoriated welding rods used in TIG welding are tungsten electrodes with a 1–4% thorium oxide (ThO_2) content. This type of welding is used in industry for aluminium and stainless steel. Metallurgical industries present a high potential risk for workers.
- External exposure and inhalation and ingestion of thorium in contaminated dust during various production operations has to be evaluated.

Relevant pathways

The pathways by which workers could receive a significant radiation dose are:

- ✓ external irradiation,
- ✓ inhalation of dust,
- ✓ inhalation of radon,
- ✓ ingestion of dirt and dust and
- ✓ skin contamination.

There are two effects that are relevant in the case of potential effects of NORM on human health and the environment:

The concentrations of NORM can be enhanced above its natural levels in a product, by-product or residue.

The availability for release into the biosphere of the NORM in products, by-products or residues can be enhanced through physicochemical changes or simply due to the method by which the residues are managed.

If the residues containing naturally occurring radionuclides are not managed properly and safely, contamination over large areas is possible given the large quantities of such residues.

Regulatory aspects

- Radon: dwellings, the action levels for remedial action is an annual average of 200-600 Bq/m^3, for workplaces is 500-1500 Bq/m^3.
- The derivation of activity concentration values for radionuclides of natural origin other than radon took into consideration the worldwide distribution of concentrations of radionuclides of natural origin in soil.
- Occupational exposure to NORM falls within the scope of the requirements for practices if the radionuclide activity concentration in the material exceeds 1 Bq/g for uranium and thorium series radionuclides or 10 Bq/g for potassium-40.
- If the relevant activity concentration level for radon or NORM is exceeded, a 'graded approach' to regulation should be applied, being the regulation in accordance with the characteristics of the operation and the exposures involved.