Surface contamination of the acrylic from radon progeny plate out

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Surface contamination due to ^{222}Rn progeny plate out: how much should we have to care about it in DS20K?

- Can we store and install the VETO acrylic panels in an ambient with normal air?

- Same question for the TPC panels

- Radon in the air

1) it diffuses inside the acrylic

2) Radon progeny plate out on surfaces

Here we share a very rough estimation to trigger a discussion…

Radon decay chain
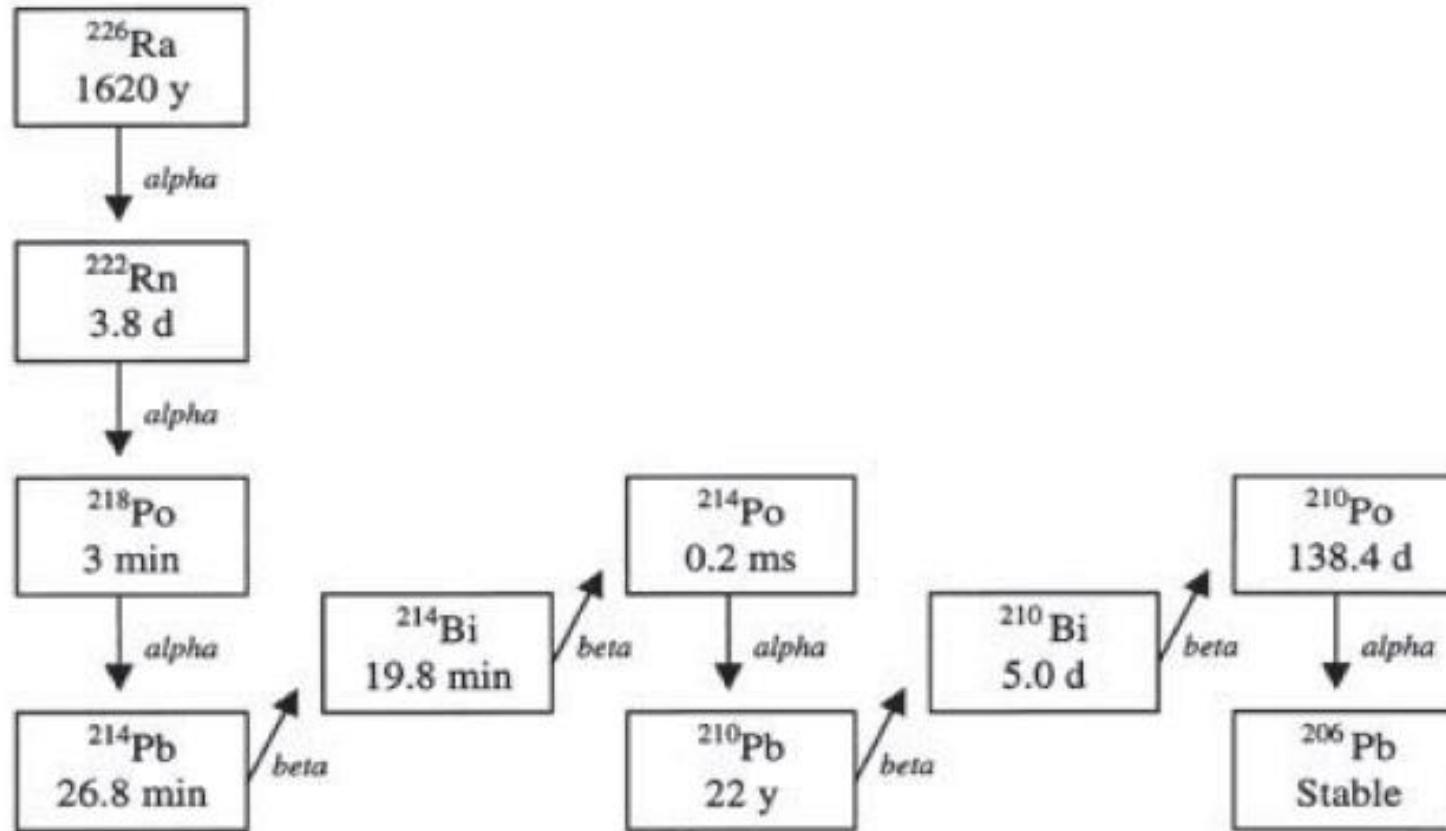
Radon progeny plate out

- All isotopes of the chain before ^{210}Pb rapidly (few hours) fully decay leaving a source of ^{210}Pb (22 years decay time) in the surface.

- ^{210}Pb β decays to Bi and then (5 days lifetime) to ^{210}Po.

- ^{210}Po (138 days decay time) is the serious concern because it is an α emitter.

- The α in the surface in 50% of the cases goes into the acrylic and can make αn reaction in the acrylic

  This is the potential issue.....

- We have to care about ^{210}Po that directly plates out from the air and ^{210}Po produced in the sample as a consequence of the plate out of ^{210}Pb and the short lifetime isotopes

Radon progeny plate out: simplified model to get rough numbers

- Consider an acrylic panel with surface S exposed to normal air for a time ΔT
- Here we make an estimation in the worst case scenario to understand how big is the problem
- We assume that there is no air filtration and that the air surrounding the panel has a very large volume
- We assume that Rn and its progeny **are in saecular equilibrium**
- We assume that there is no removal of Rn daughter other than deposition on the surface and that the volume of air is so big that this deposition does not affect the air activity.
- The concentration of every Rn progeny is obtained as

$$\frac{C_{Ra}}{\tau_{Ra}} = \frac{C_i}{\tau_i}$$

where i = ^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po, ^{210}Pb, ^{210}Bi, ^{210}Po

and C_{Ra} and C_i are the number of atoms/m^3 and τ_i are the isotope decay times

- A reference value for radon activity in air Rn activity in air of A_{Rn}=10 Bq/m^3

How many atoms are absorbed on the surface??

Number of atom per unit of surface adsorbed versus time $\Longrightarrow$ $N_i = C_i V_d t$

      Ni number of atom absorbed per unit of area (atom/m²)
      Ci concentration of that atoms in the air (atoms/m³)
      V_d deposition rate m/s
      t   exposure time

Atoms are adsorbed and then they decay while others are continuosly added. We consider for the moment ^{210}Po and we neglect its decay during the exposure time (only to make a rough fast calculation).
We use the previous hypothesis of saecular equilibrium to get C_{210Po}

Vd : typical values found in literature are 5-15 m/hours.
    Of course it depends on many factors ... but just take an order of magnitude

Number of atom of ^{210}Po per unit of surface adsorbed during the time ΔT

$$N_{210Po}(atoms/m^2) = \frac{C_{Rn}}{\tau_{Rn}} \tau_{210Po} V_d \Delta T = A_{Rn} \tau_{210Po} V_d \Delta T$$

Estimation of the VETO surface, considering also 3-4 sectors for each edge of the octagon: S= 500 m²

After the exposure, we suppose to move the sample in a radon free environment (the DS20K apparatus).
^{210}Po will decay with 138 days lifetime.
In 5 years of data taking basically all the ^{210}Po is decayed producing neutrons with yield Y= 8.8 10^{-7} n/ decay
The total number of neutrons in 5 years is then

$$Number \ of \ neutrons = 0.5\,Y\,S\,N_{210Po} = 0.5\,Y\,S\,A_{Rn}\,\tau_{210Po}\,v_d\,\Delta T$$

With S= 500 m^2
  A_{Rn}= 10 Bq/m^3
  Y=8.8 10^{-7} n/decay
  V_d= 10 m/hours= 2.7 10^{-3} m/s
  ΔT= 1 day of exposure to radon (as example)
  we get 6 10^6 neutrons
This is about 6 10^3 times the contribution from Gd in the VETO !!!!
So, under these hypothesis, with 1 day of exposure to normal air, we get 6 10^6 neutrons from the direct plate out of Po210. The contribution increases with the exposure time.

Also we need to add the contribution due to plate out of 210Pb and of the short lifetime isotopes.

The situation is better in a clean room with proper air filtration where we can get vd= 3 10^{-8} m/s
(5 order of magnitudes better than above) but still the exposure time must be limited
(see M. Leung *Topical Workshop on Low Radioactivity Techniques (2005)*)

Cleaning of the surfaces must be discussed and probably implemented???

Comments

- These calculations are very rough but they suggest that Radon progeny plate out is an issue to care about
- If these results are confirmed then the acrylic (for the VETO and TPC) cannot stay exposed to normal air
- It needs to be stored in a radon free environment (packed and sealed in nitrogen atmosphere,radon free)
- Handling must be done in clean room with air filtration
- Installation inside the DS20K cryostat also must be done creating a clean room with low Radon level inside the cryostat itself
- Note that in G. Sasso the Rn activity of the air is much higher than what we quoted here
- Our calculations only consider direct plate out of ^{210}Po but also the others progeny must be included.

- Rn diffusion is not discussed here and it may worsen the issue.

So the number of neutrons is
Number of neutrons in 5 years =

Inserting some numbers

$$\frac{N_{210Po}}{\tau_{210Po}}(Bq/m^2) = A_{Rn}v_d\Delta T$$

Take 1 day as a reference

10 Bq/m3   10 m/hours

$$\frac{N_{210Po}}{\tau_{210Po}}(Bq/m^2) = 2.4\,10^3\,\Delta T_{days}$$

Estimation of the VETO surface, considering also 3-4 sectors for each edge of the octagon: 500 m²

Qestion: how much surface contamination will be accumulated on the acrylic s