LEACHING RADON DAUGHTERS FROM MATERIALS OF LOW BACKGROUND DETECTORS INTO WATER AND LS

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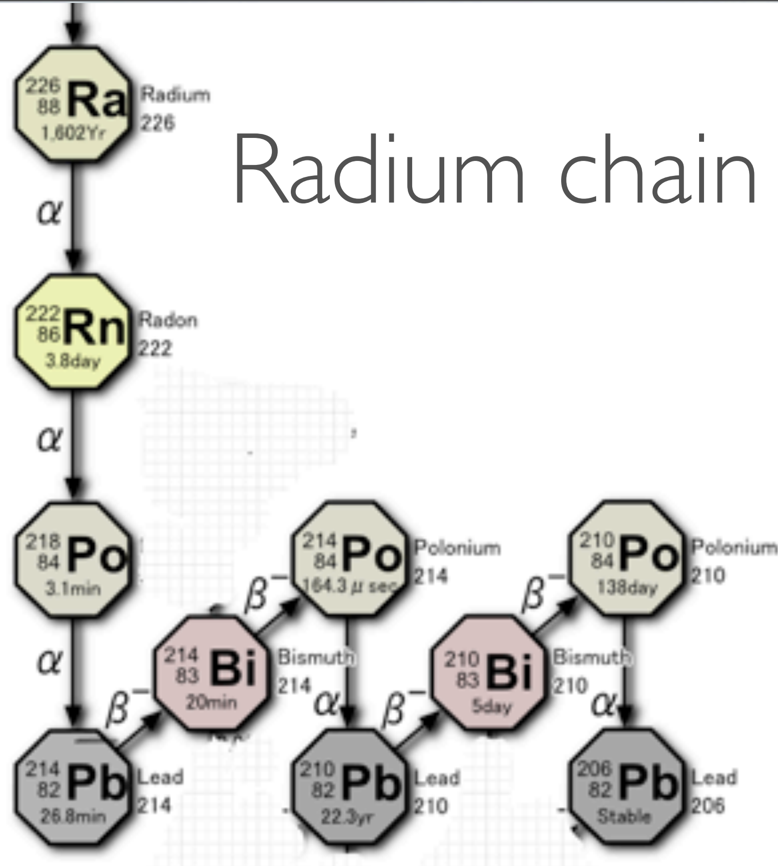
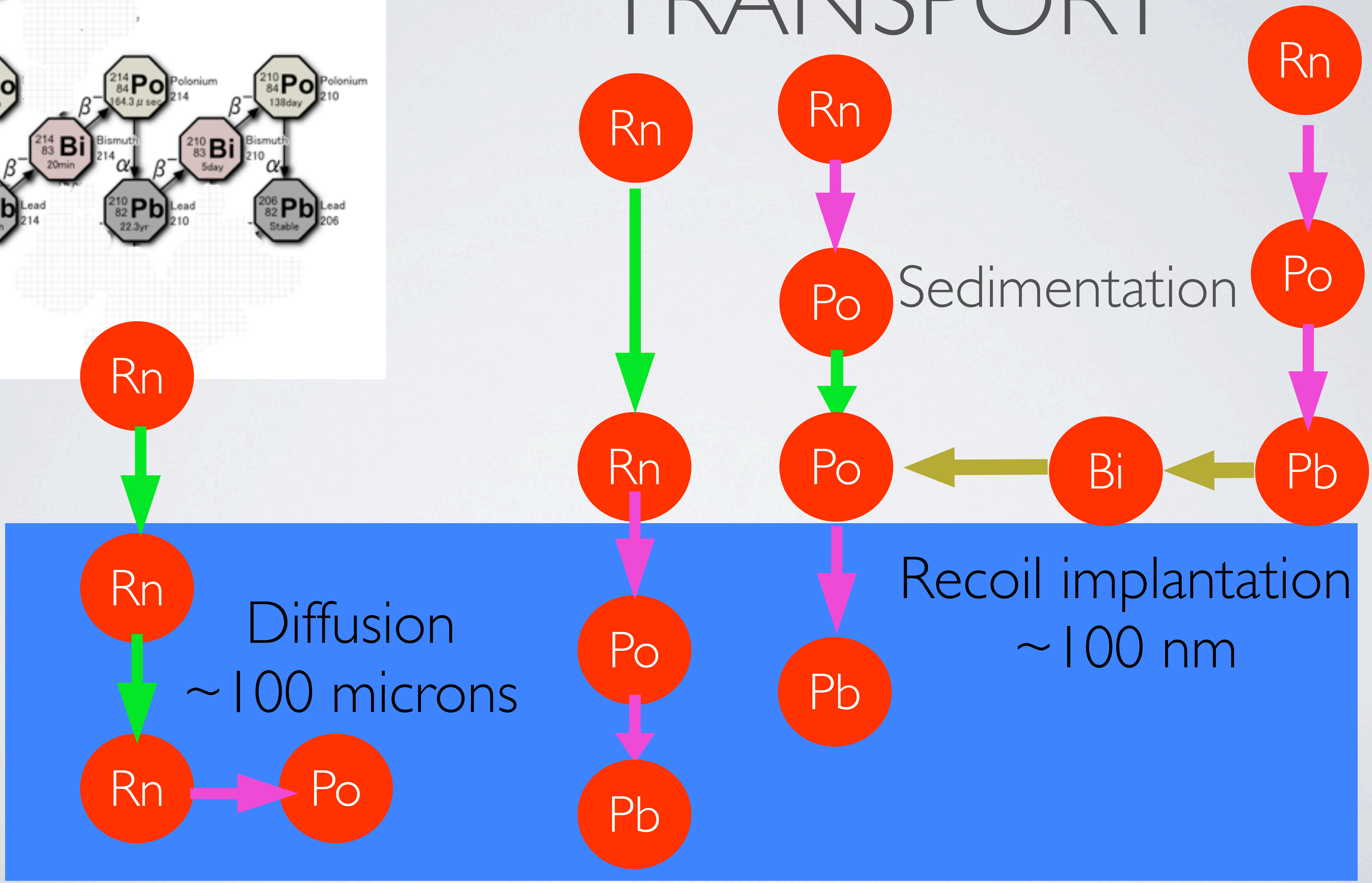
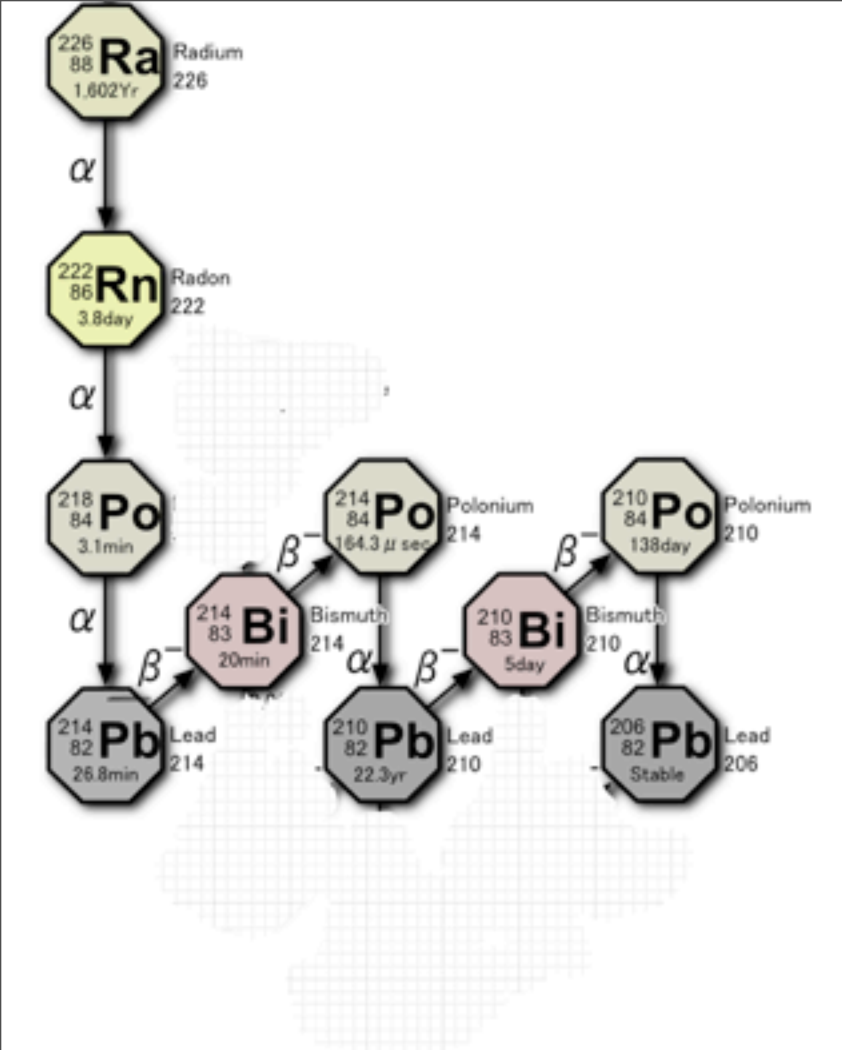
OUTLOOK

- Radon and daughters transport to surface
- Desorption from surface
- Experimental approach and technique
- Results of measurements with various materials
- Results of measurements with SNO vessel acrylic
- Conclusions

RADON DAUGHTERS TRANSPORT







RELATIVE CONTRIBUTION OF SEDIMENTS AND DIFFUSION

Case of big spherical detectors: SNO, Borexino, Kamland left over time t in air with radon concentration C

$$N_V = \frac{4\pi}{3} R^3 \times C_{Rn} \times t$$

$$N_D = 4\pi R^2 \times \lambda \times Sol \times C_{Rn} \times t$$

$$\lambda = \sqrt{D\tau}$$

$$\frac{N_V}{N_D} = \frac{R}{3 \times Sol \times \sqrt{D\tau}}$$

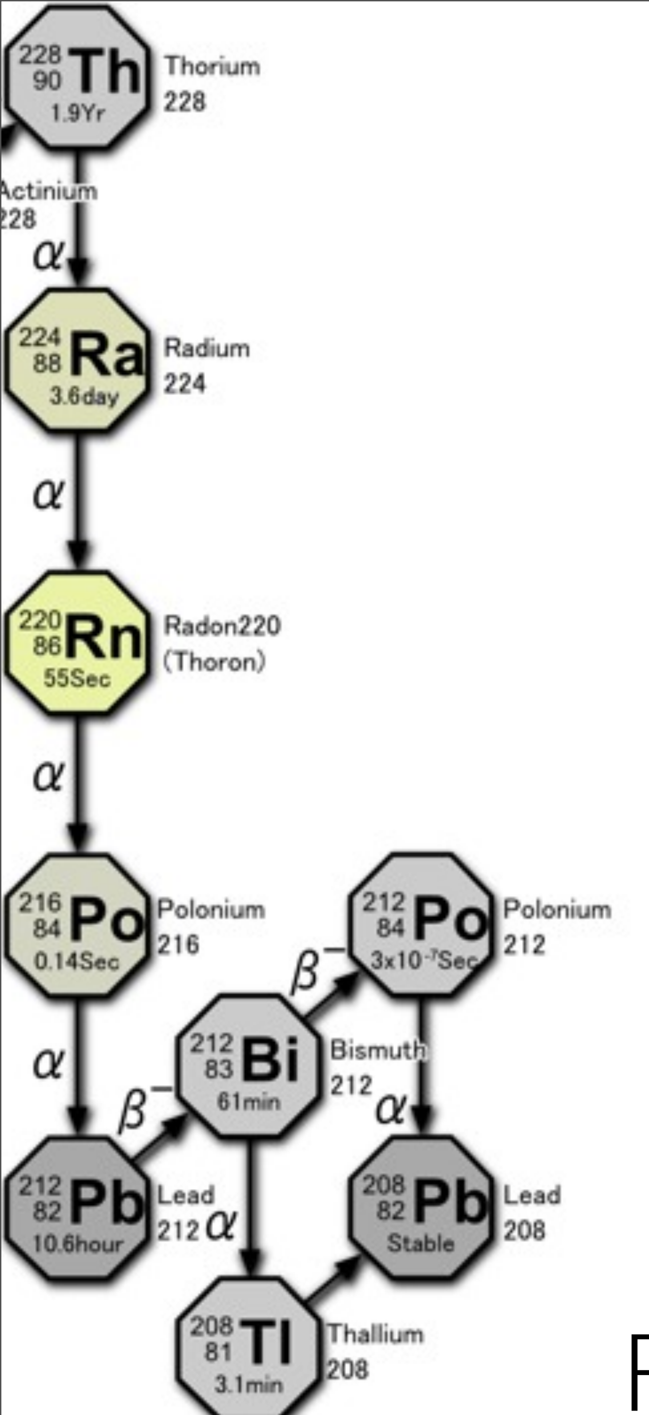
Solubility = ~10,

Diffusion length ~ 200 microns (Rn in acrylic)

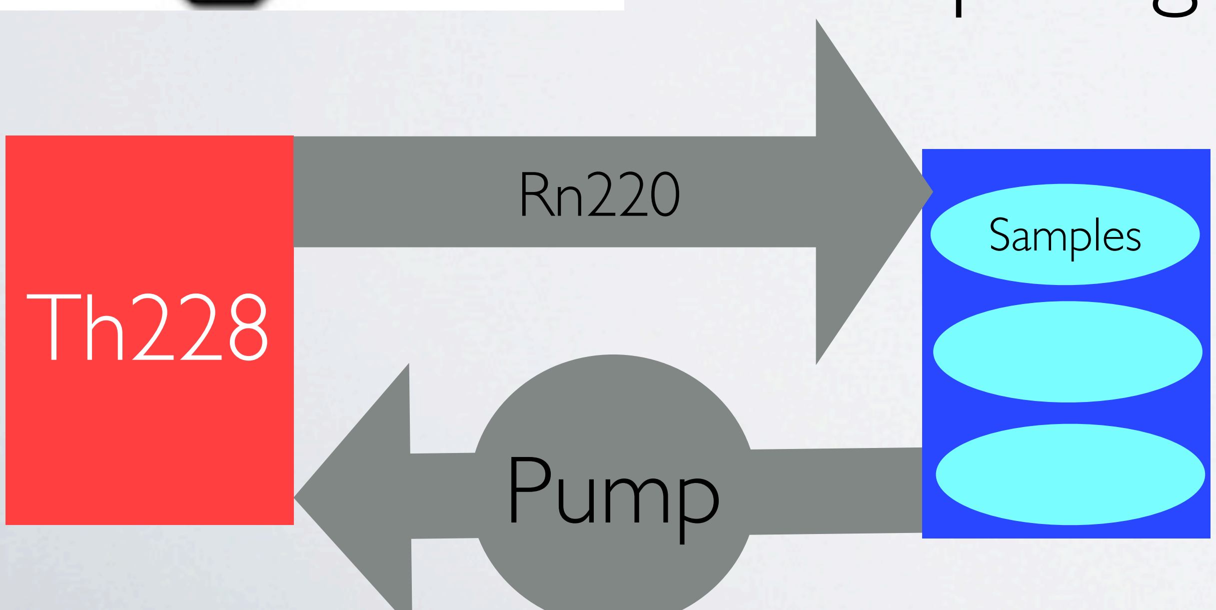
Sediments/Diffusion = 1000

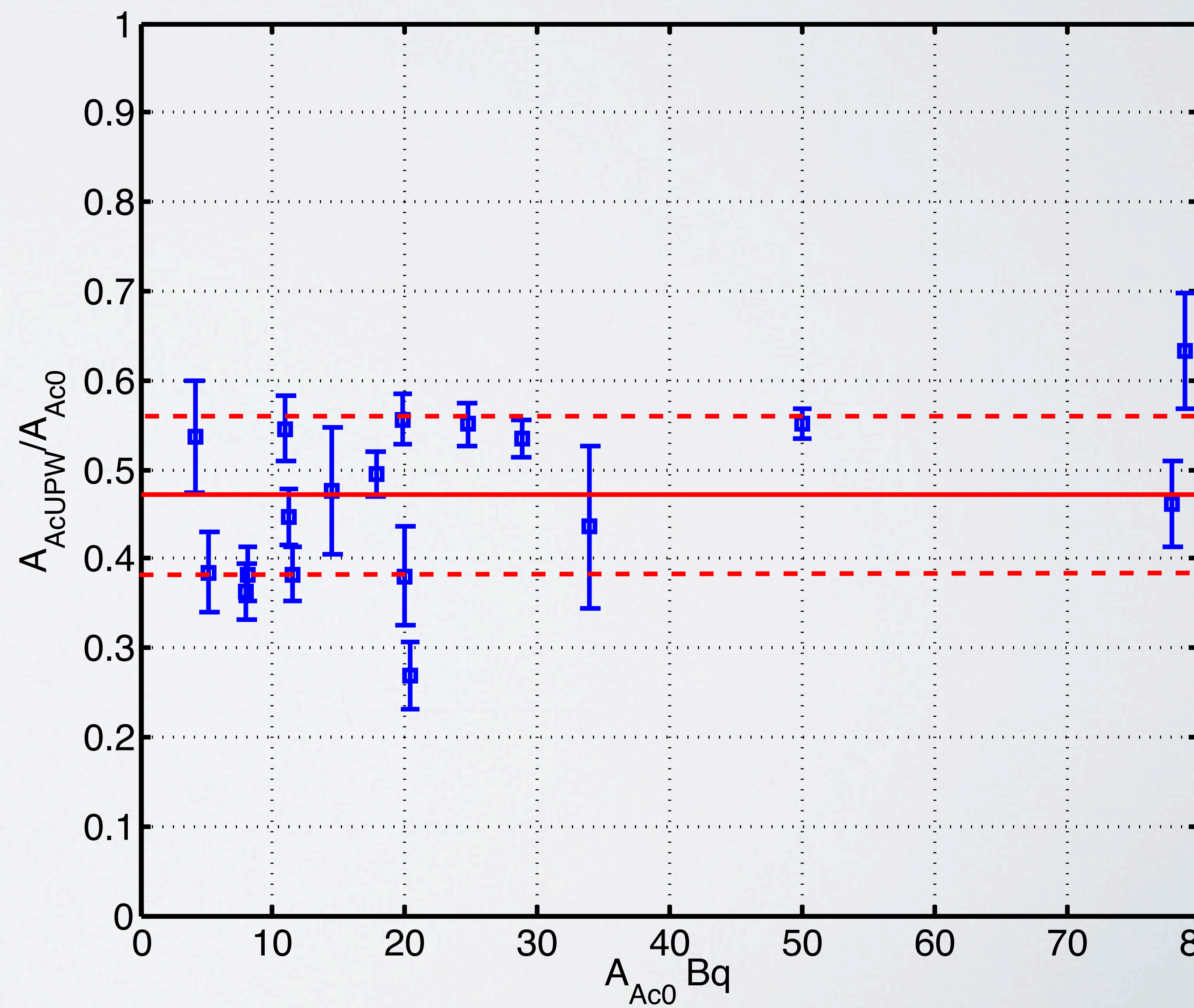
HALF OF SEDIMENTS IS IMPLANTED BY ALPHA RECOIL, BUT SECOND HALF IS EASILY REMOVED BY WATER WASH

Rn220-Po216-Pb212 spike of organic materials: acrylic, teflon, tygothene tube and tensilon

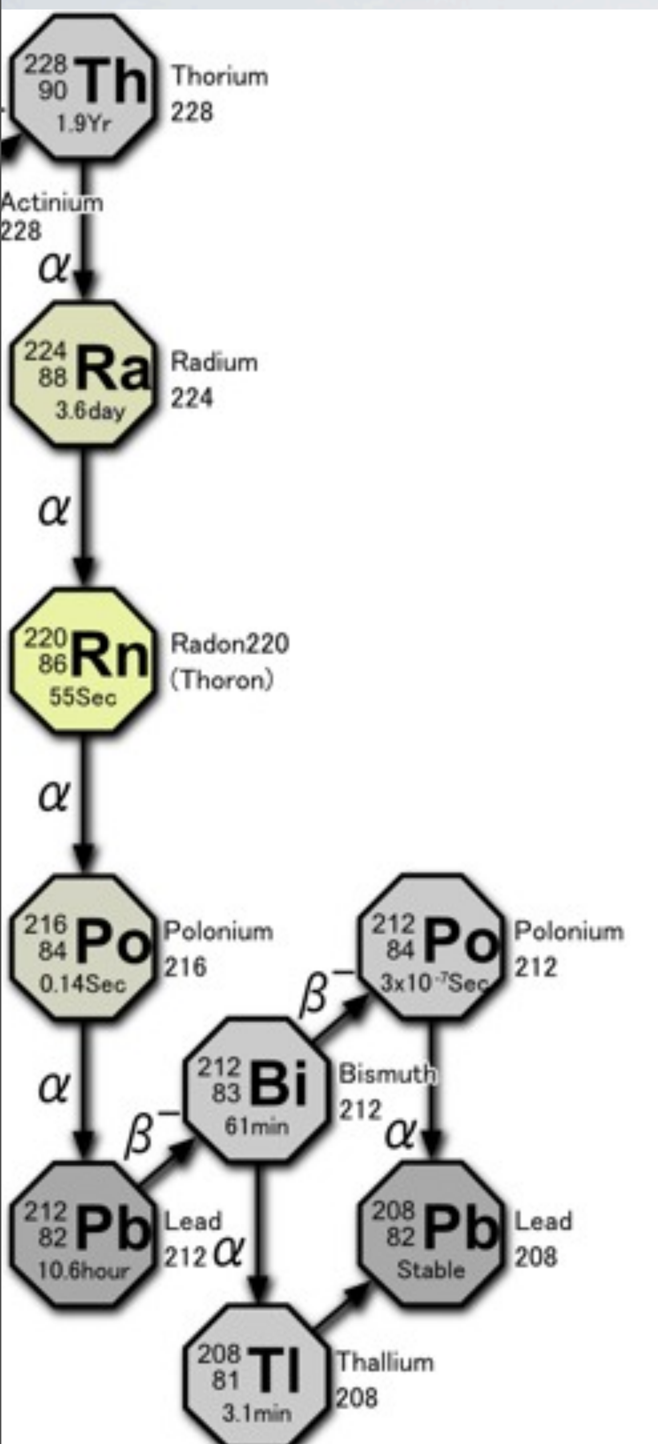


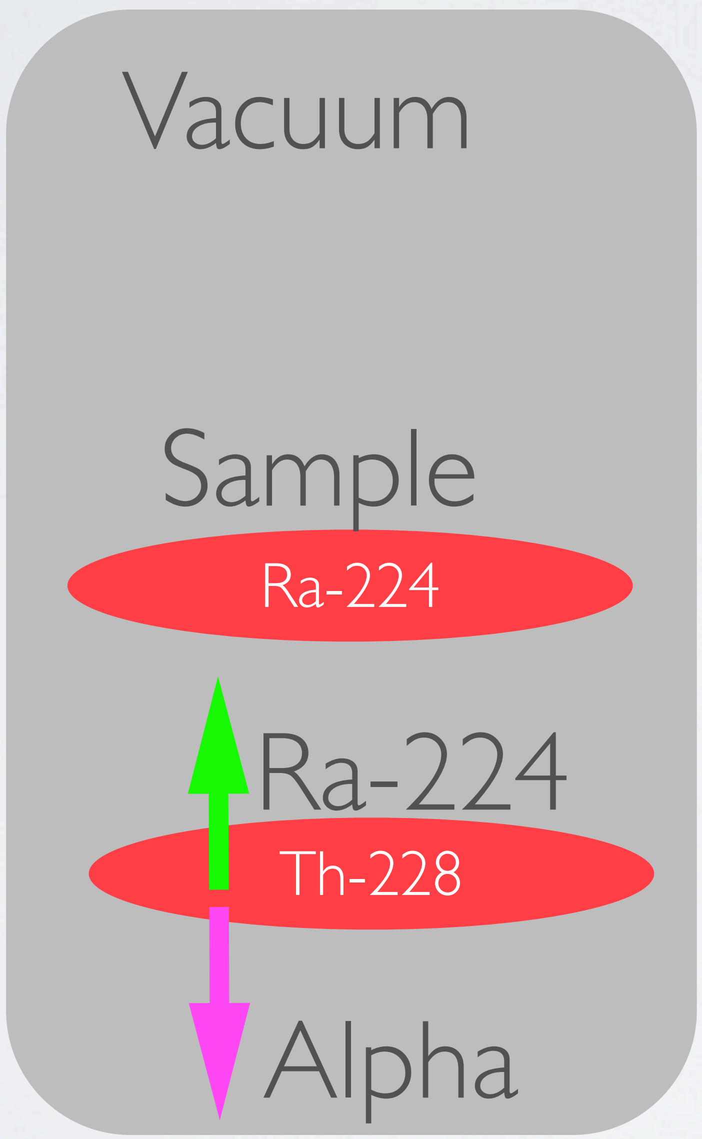
Scheme of Pb212 spiking





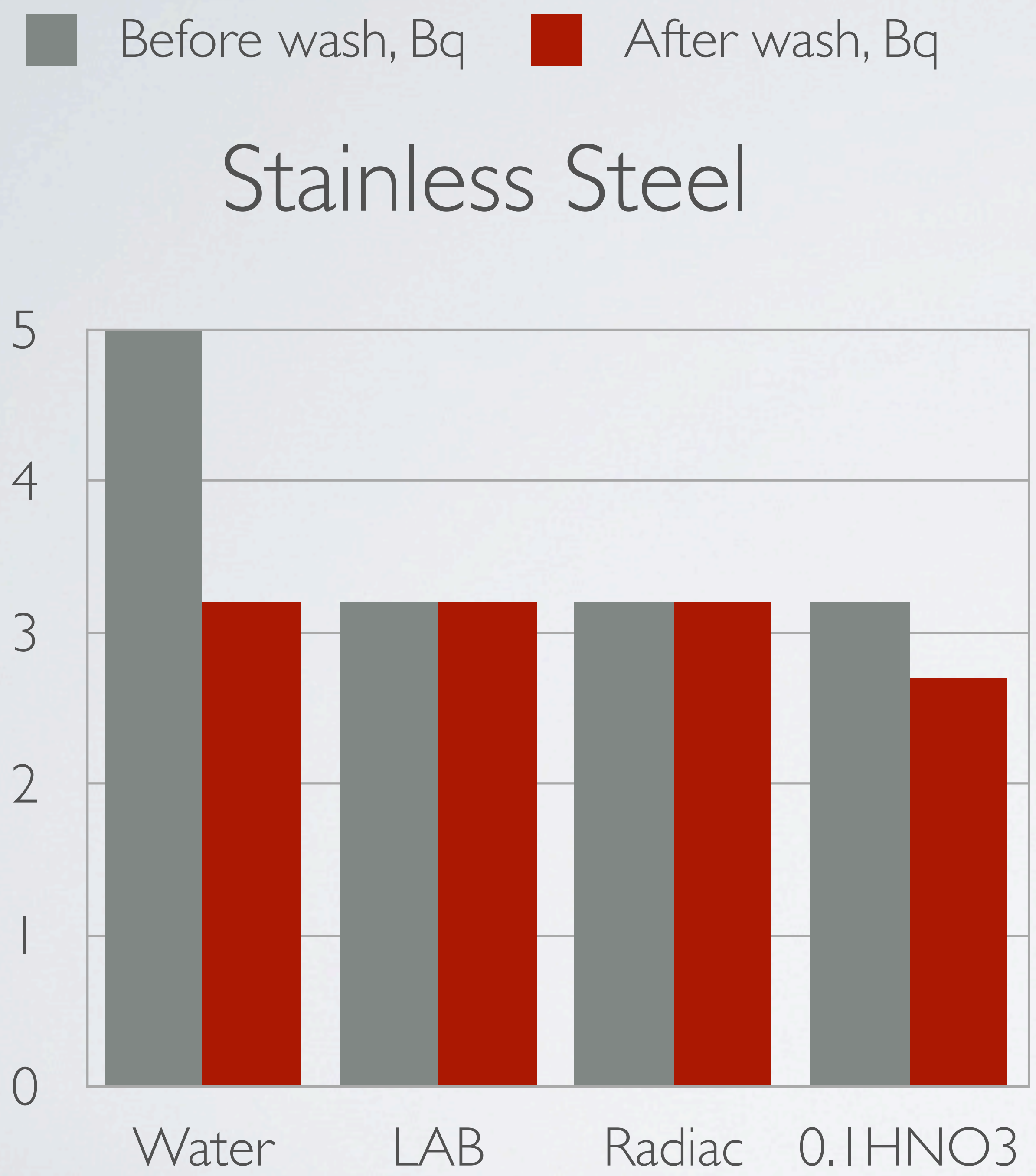
HOW ABOUT RECOILED NUCLEI WASHING? RADIUM IMPLANTATION EXPERIMENTS

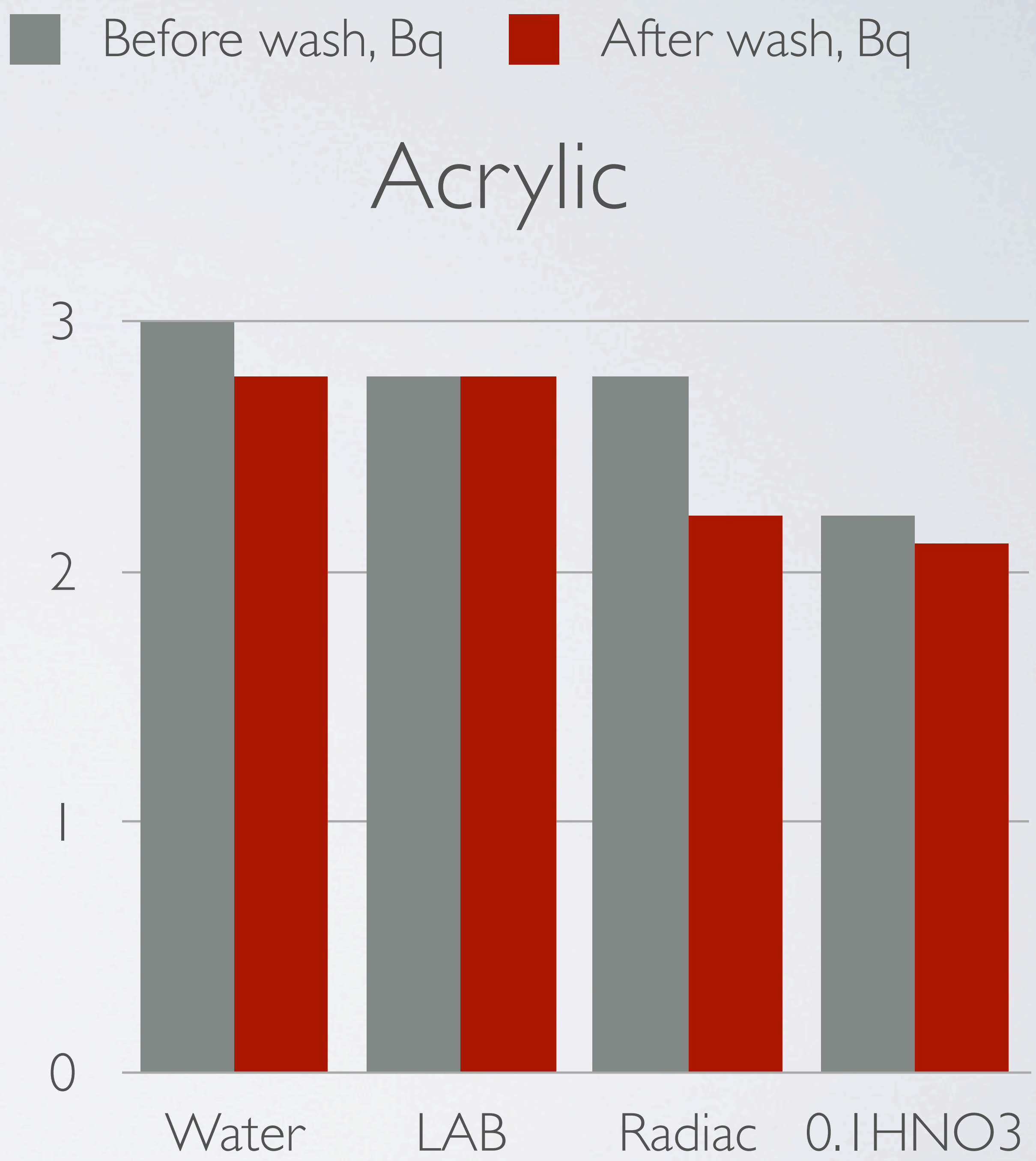


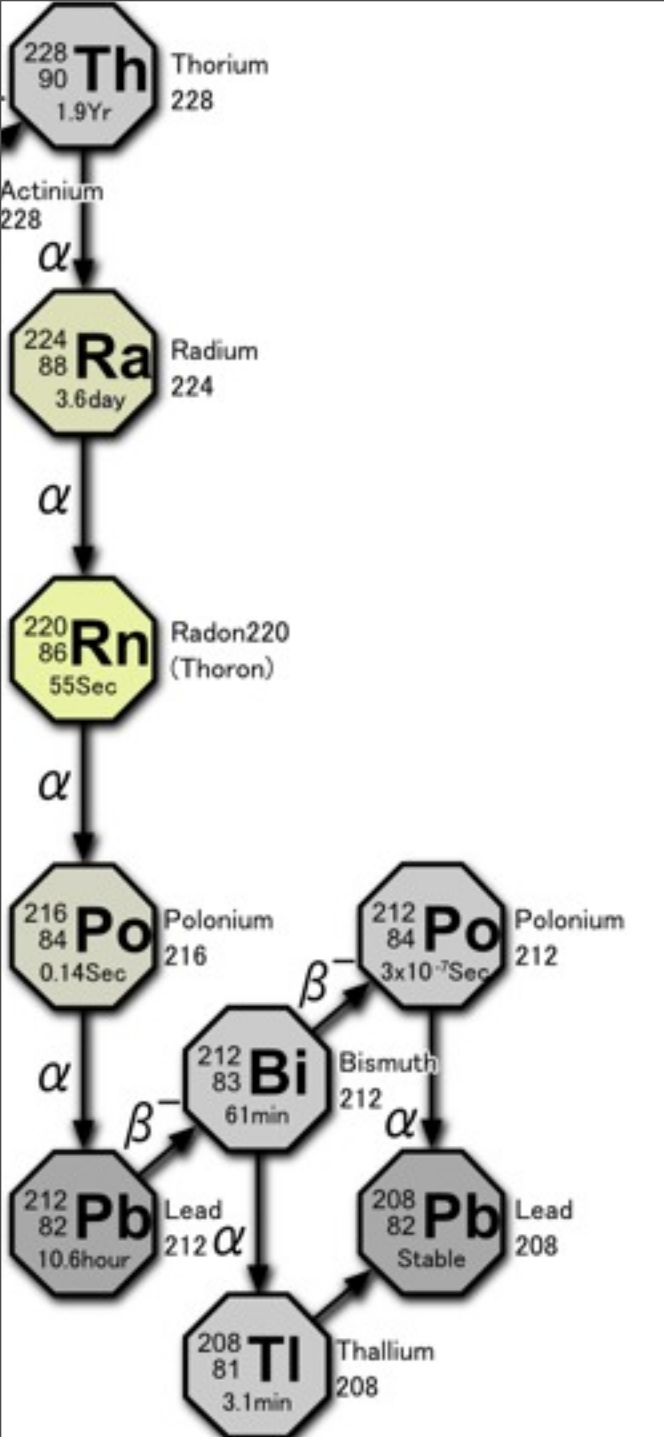


Thin source of Th-228 was prepared and put in vacuum chamber. The acrylic and stainless steel samples was placed above the source. Alpha-recoil Ra-224 was plated on the samples. The samples were alpha-counted before and after washing in various solvents: Water, LAB, Radiacwash, Nitric acid

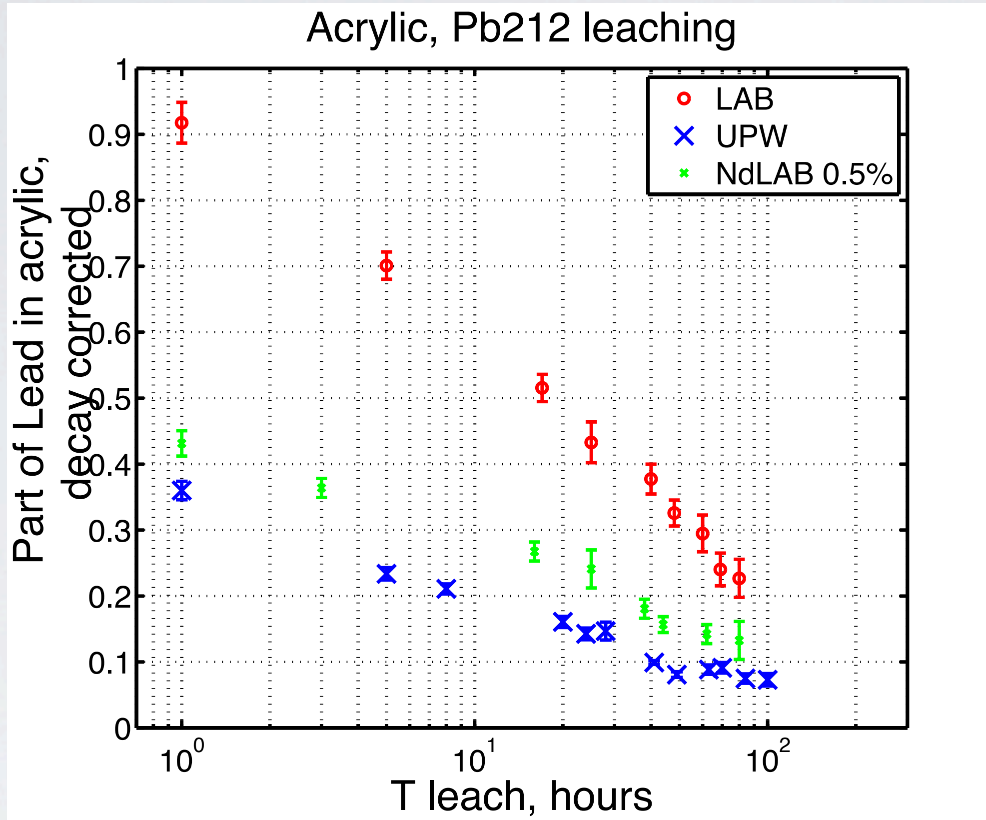
RADIUM-224 WASH OUT VERY SLOW IN LAYER ~0.1 MICRONS

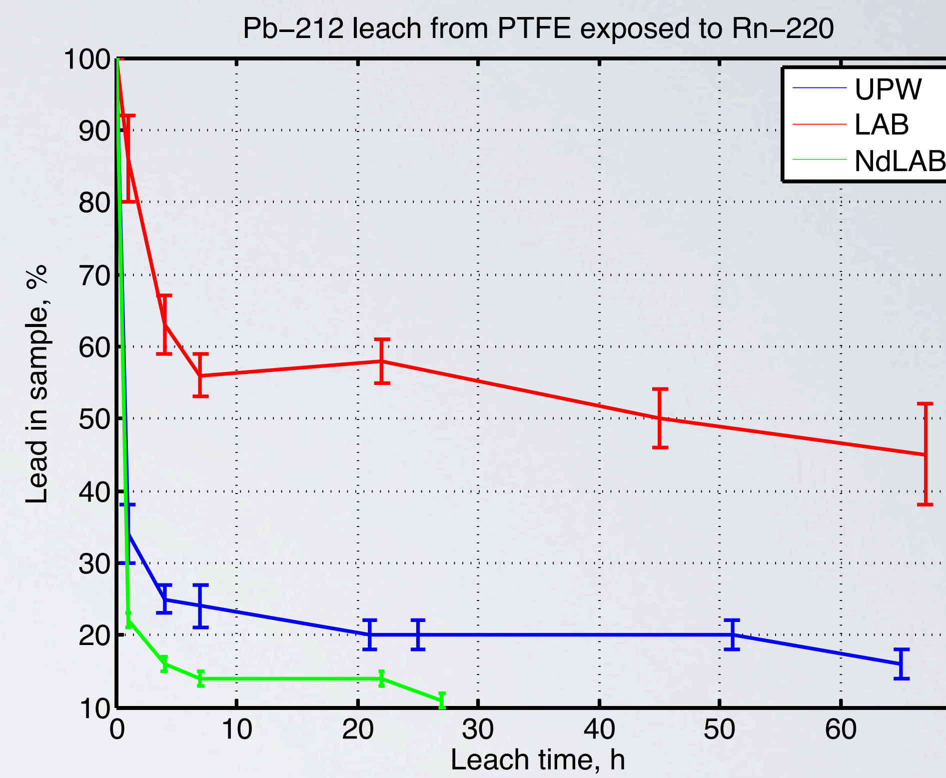


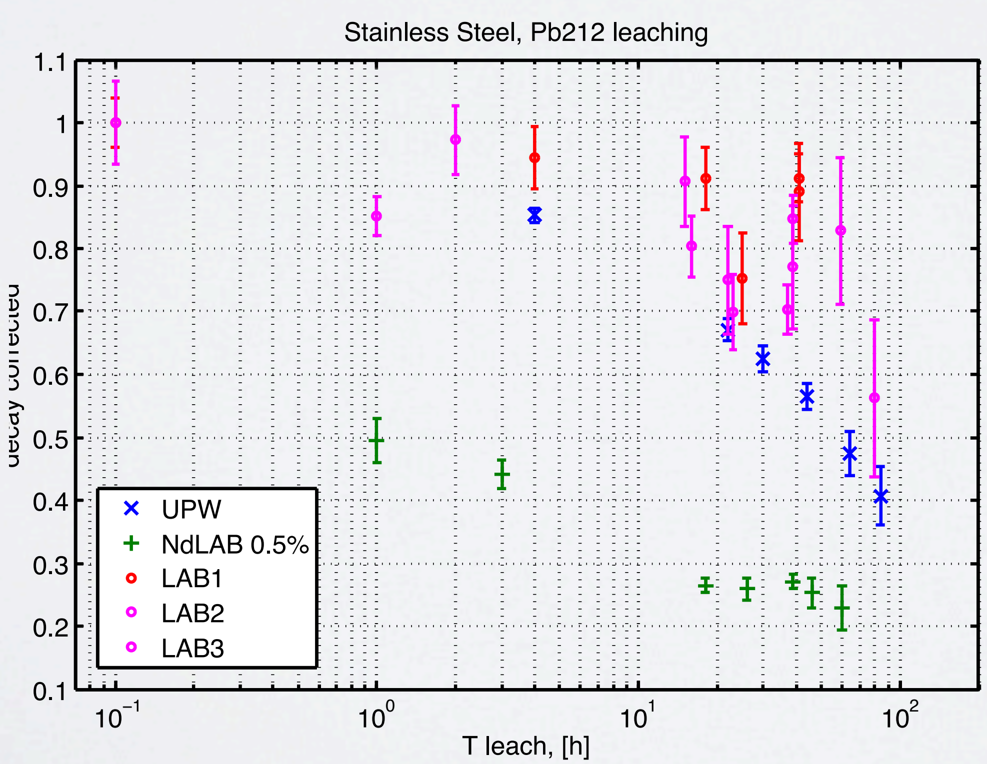


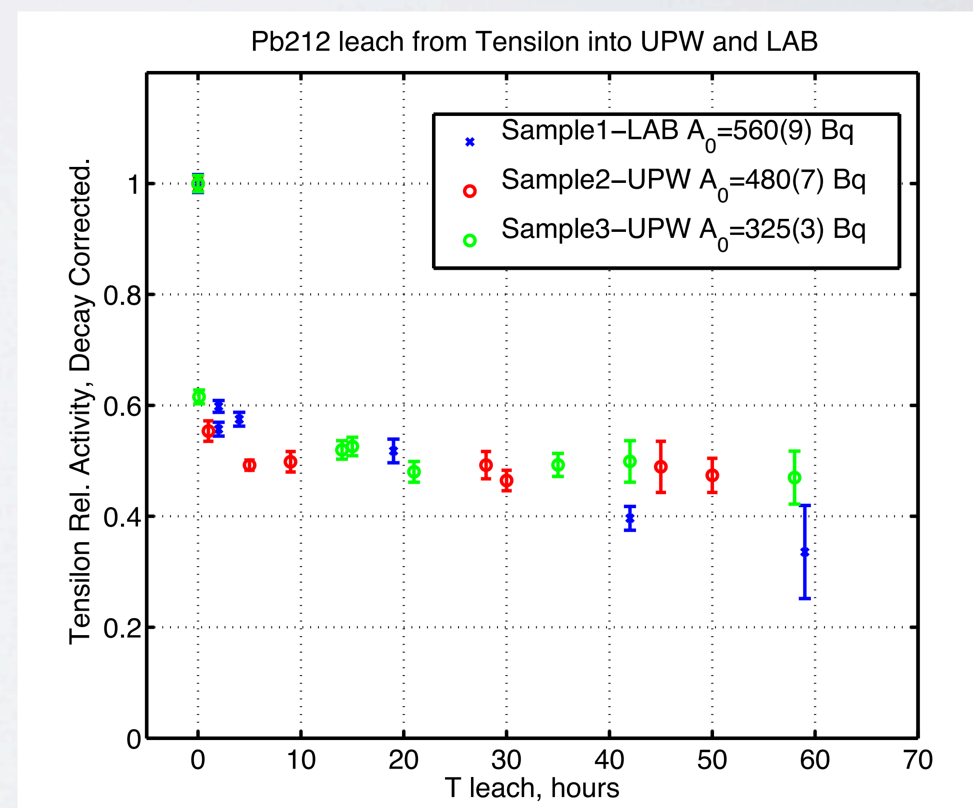


LEAD-212 LEACHING FOR SELECTED MATERIALS









RECOILS STAY STRONG.
NEED LONG TIME TO GET THEM OUT.
DIFFUSION THEORY SHOULD WORK.
LET'S LOOK!

Math of diffusion and desorption

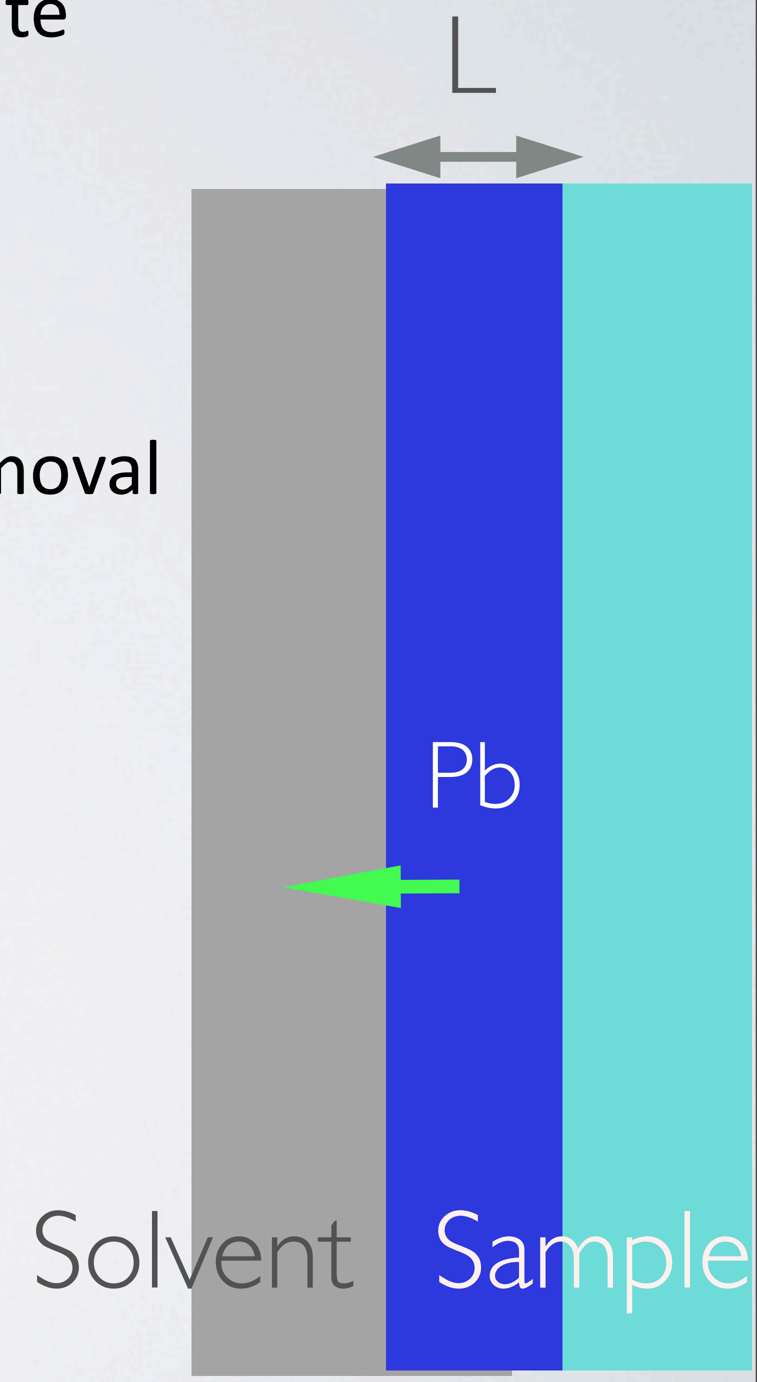
- Uniform layer with thickness L and diffusion coefficient D
- M is mass removed from the layer, LR is the leaching rate

$$\frac{M_t}{M_\infty} = 1 - \frac{8}{\pi^2}\sum_0^\infty \frac{1}{(2n+1)^2}\exp\left[-\frac{(2n+1)^2\pi^2 Dt}{4L^2}\right]$$

- $\frac{M_t}{M_\infty} = \frac{2}{L}\sqrt{\frac{D}{\pi}}\sqrt{t}$, if t < T1/2-time of half material removal

$$LR_t \equiv \frac{1}{(M_\infty - M_t)}\frac{dM_t}{dt} = -\frac{d}{dt}\ln(M_\infty - M_t)$$

$$LR_\infty = -\lim_{t\to\infty}\frac{d}{dt}\ln(M_\infty - M_t) = \frac{\pi^2}{4}\frac{D}{L^2}$$



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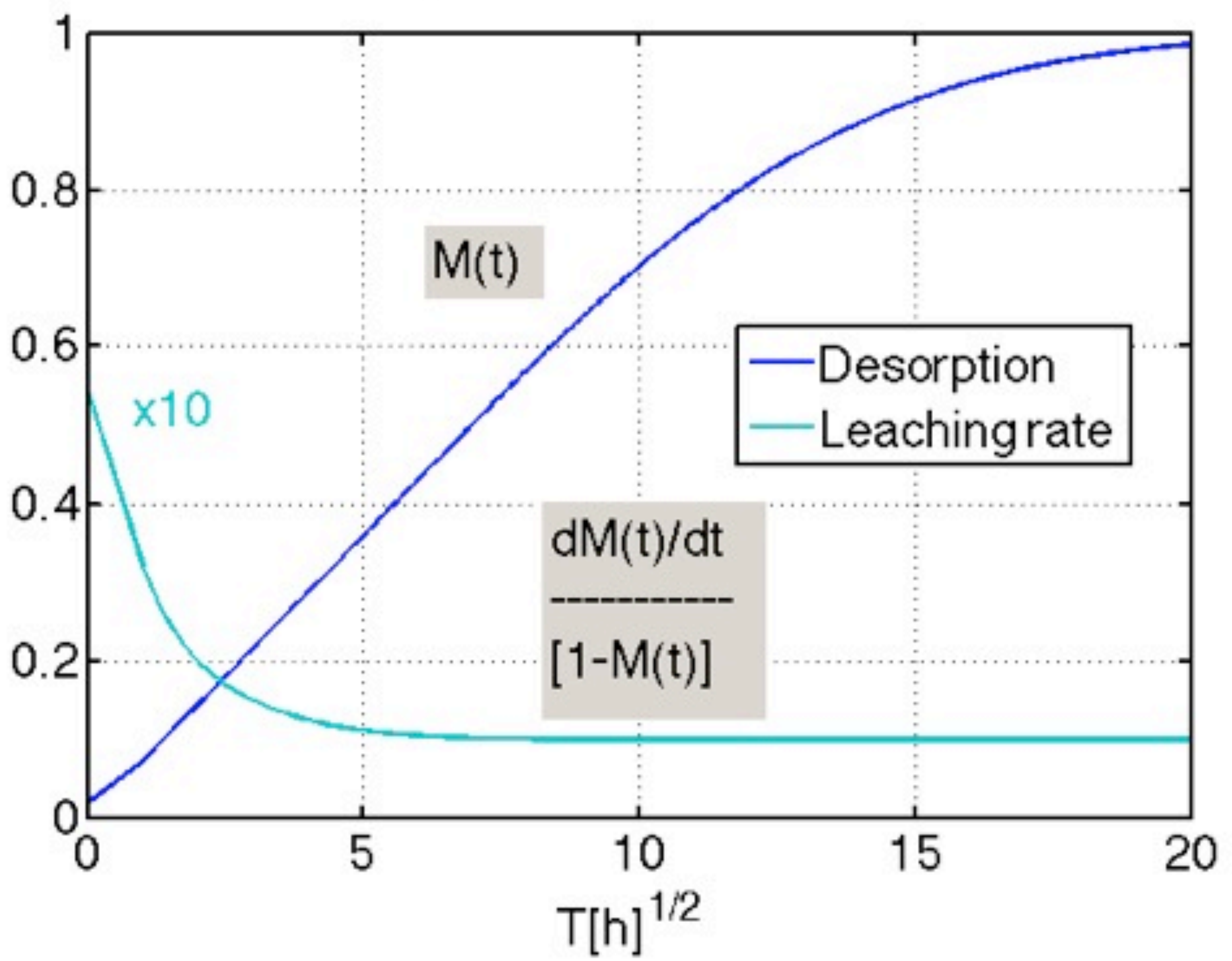
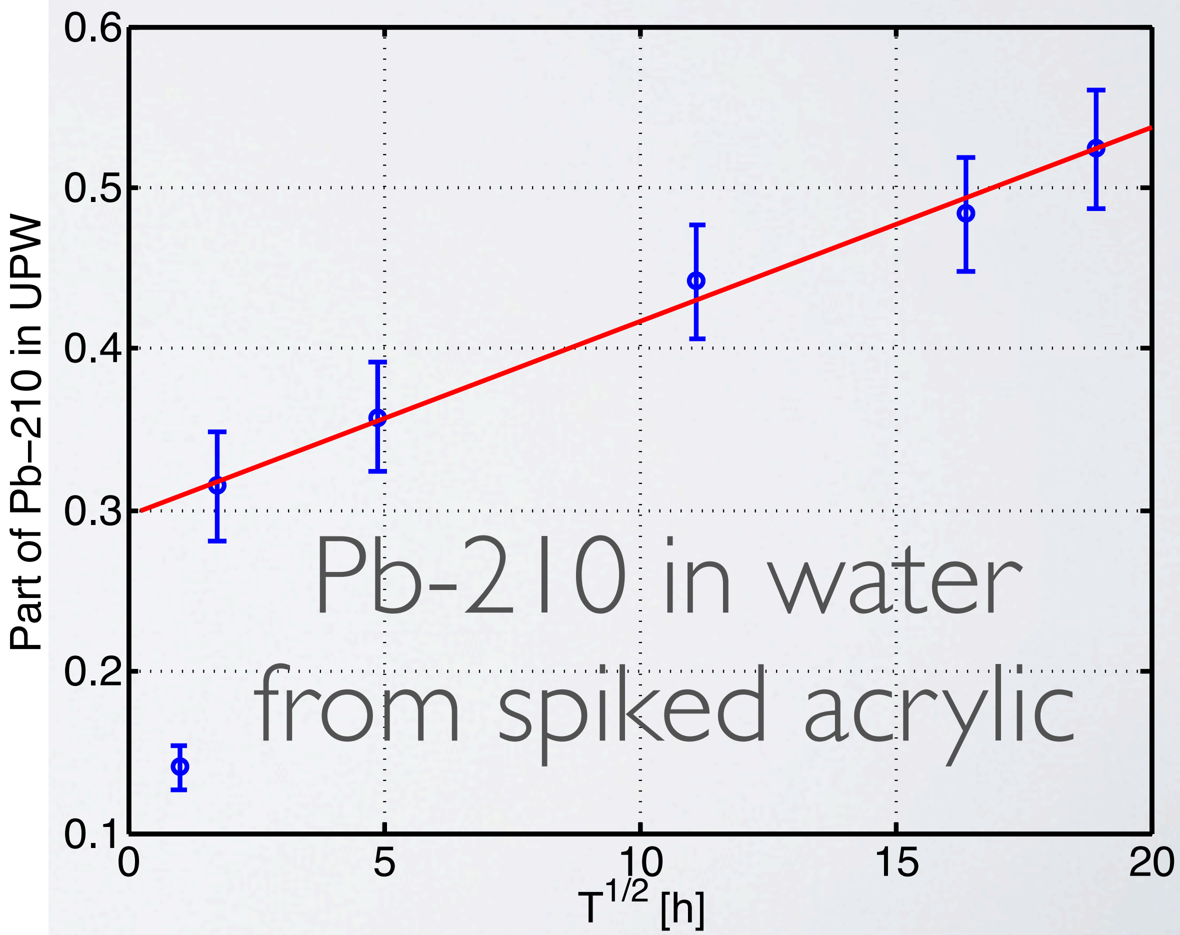
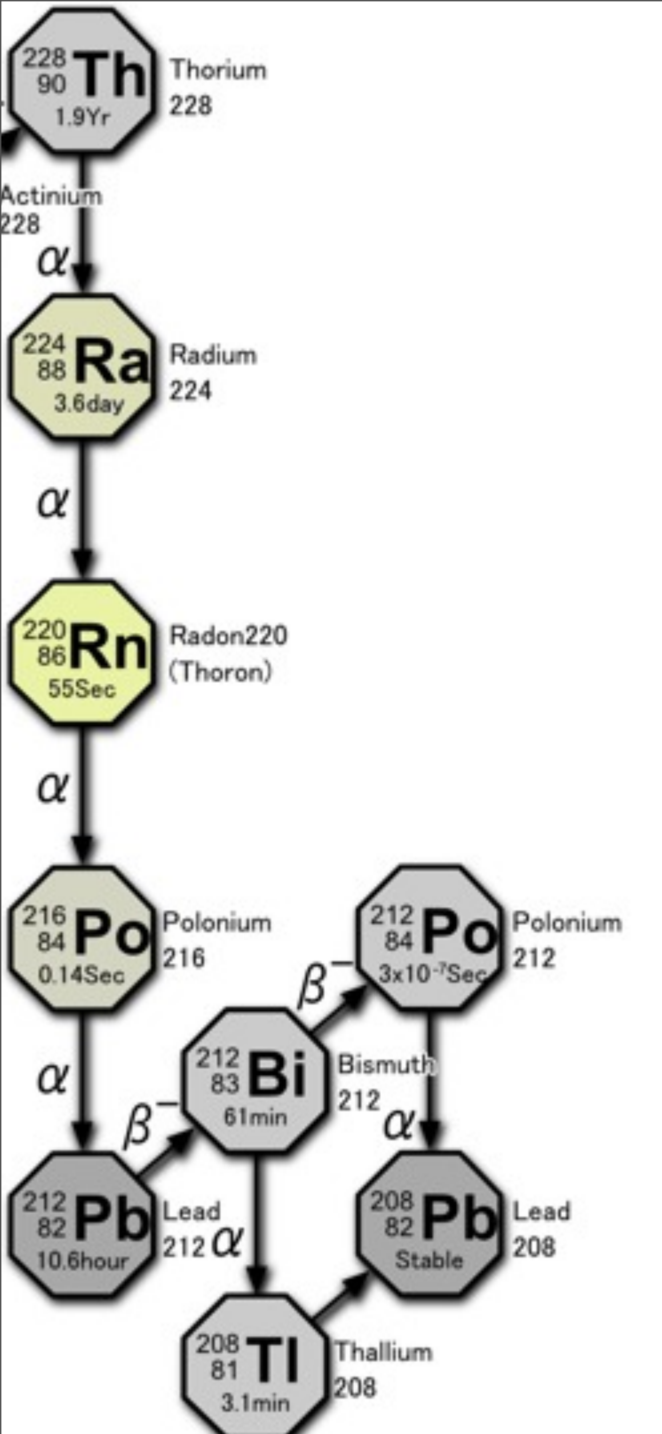
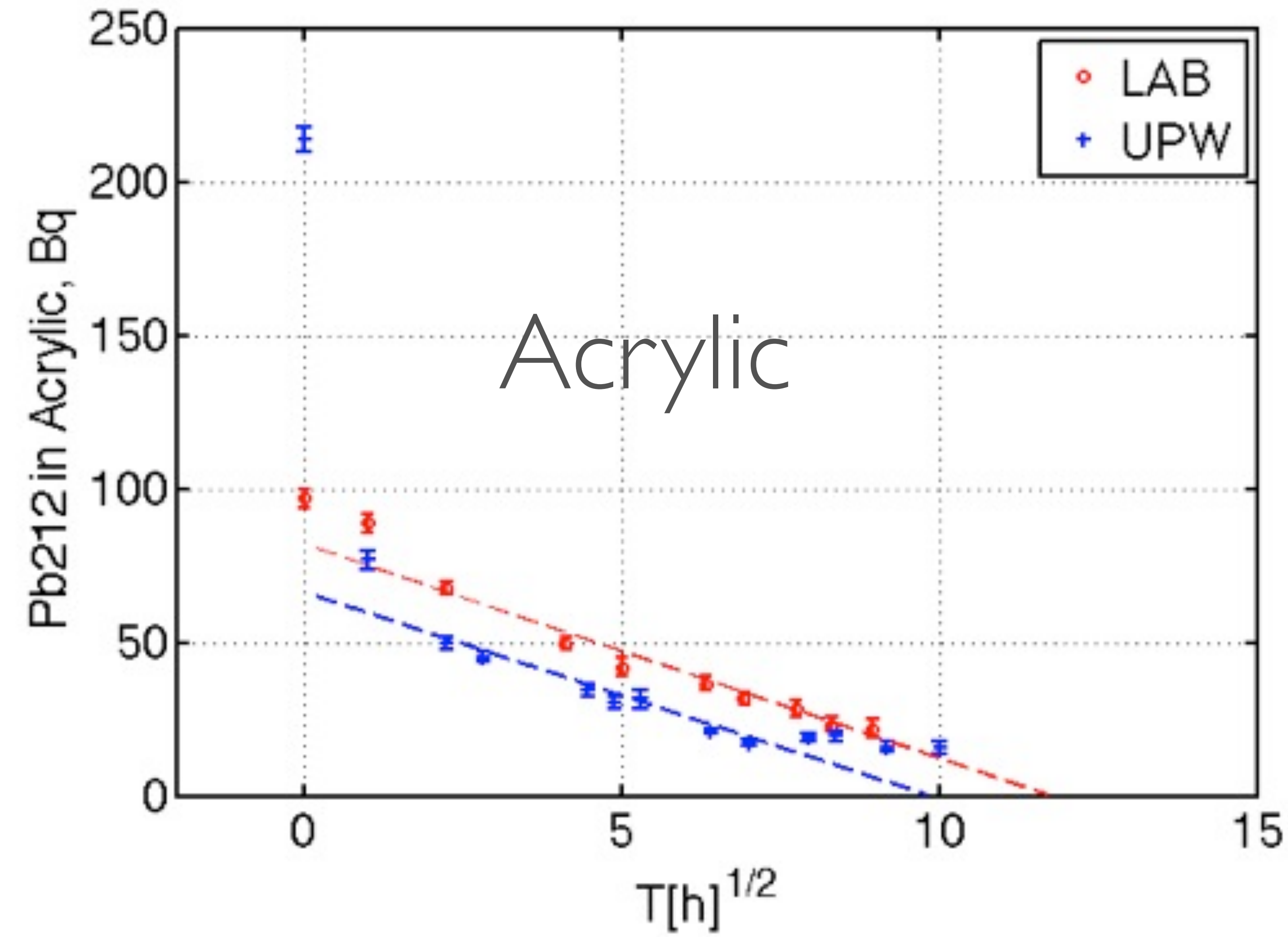
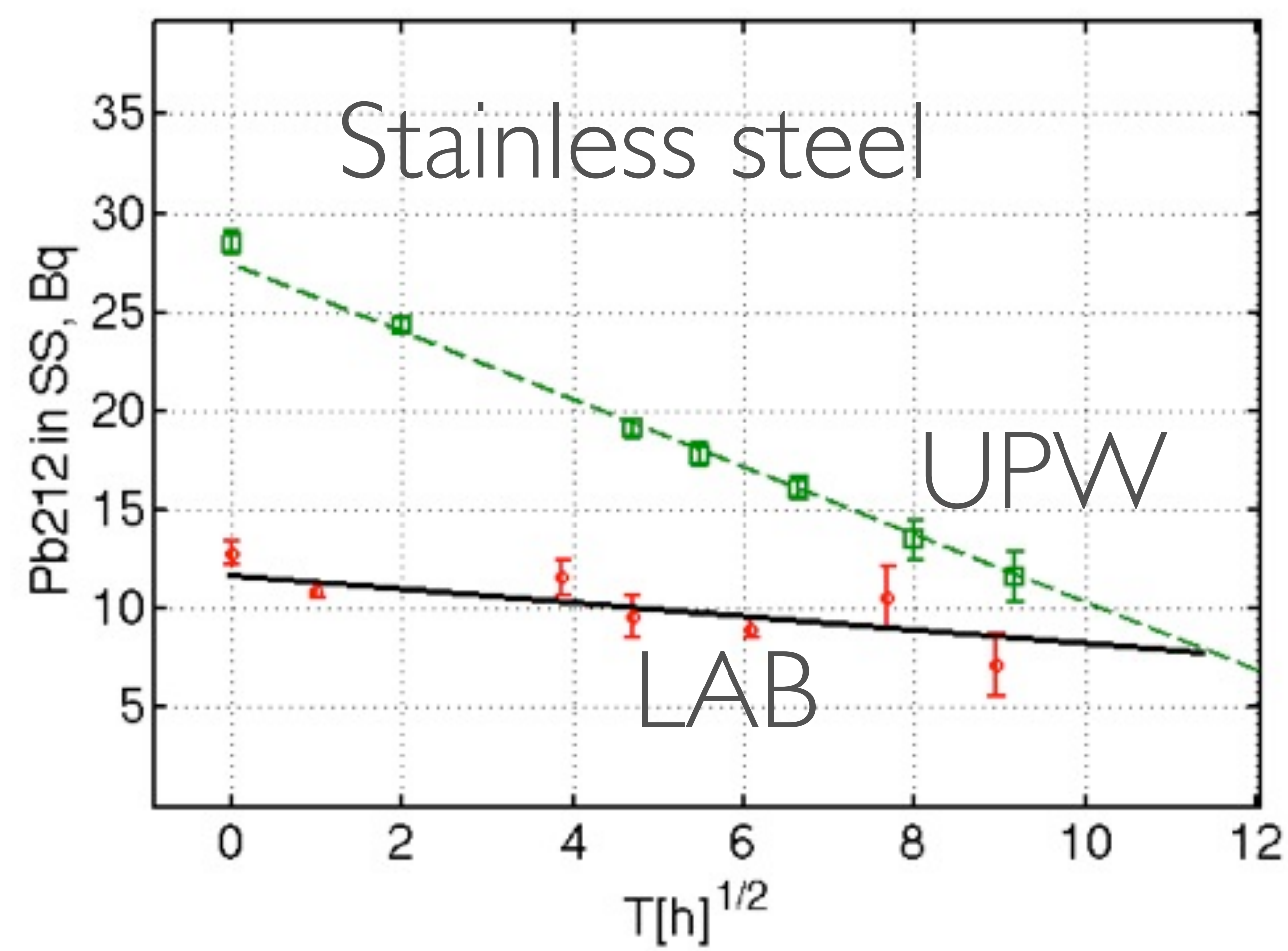
Leaching rate is defined here as the relative rate of material removal from the source.





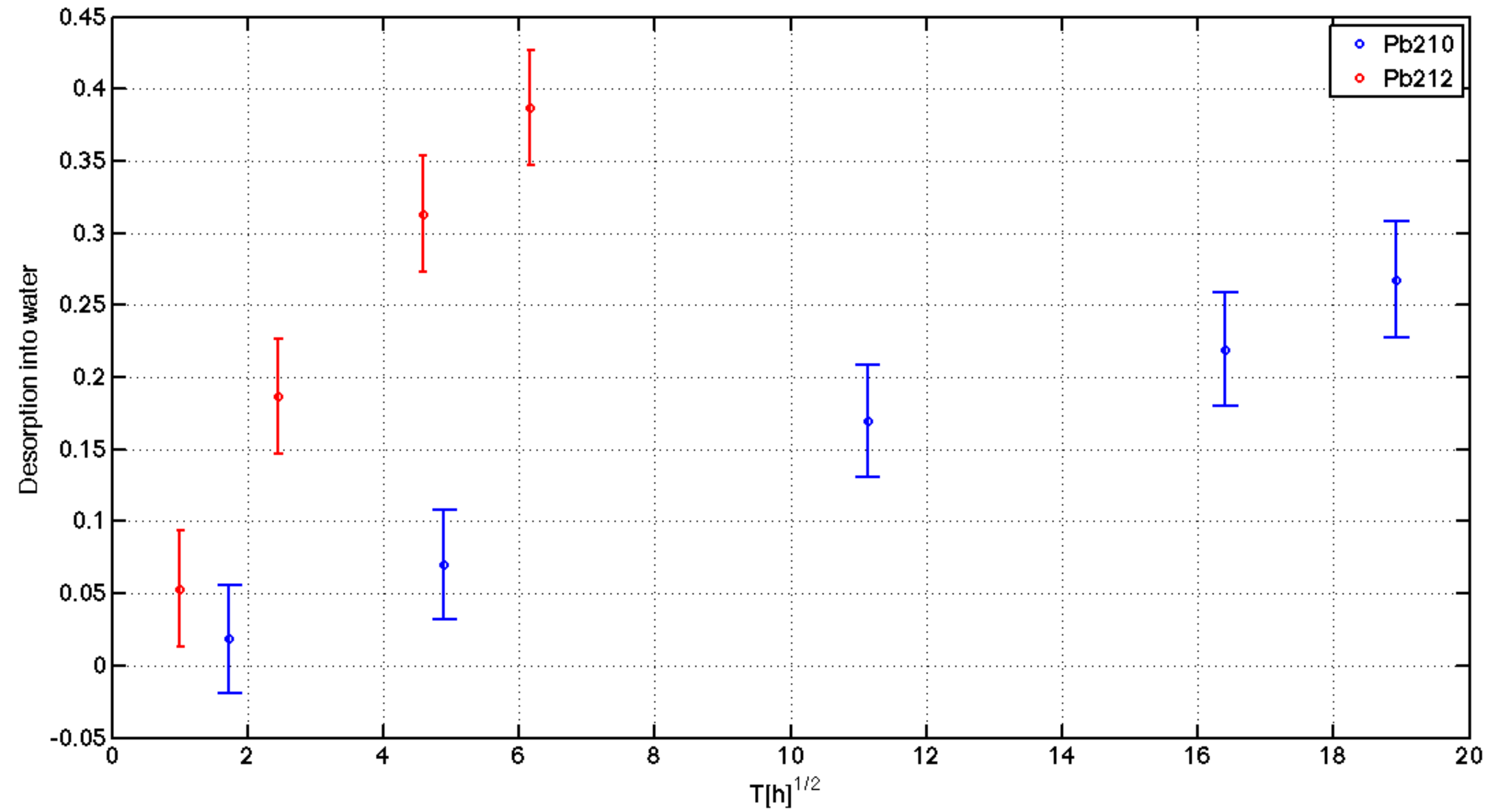


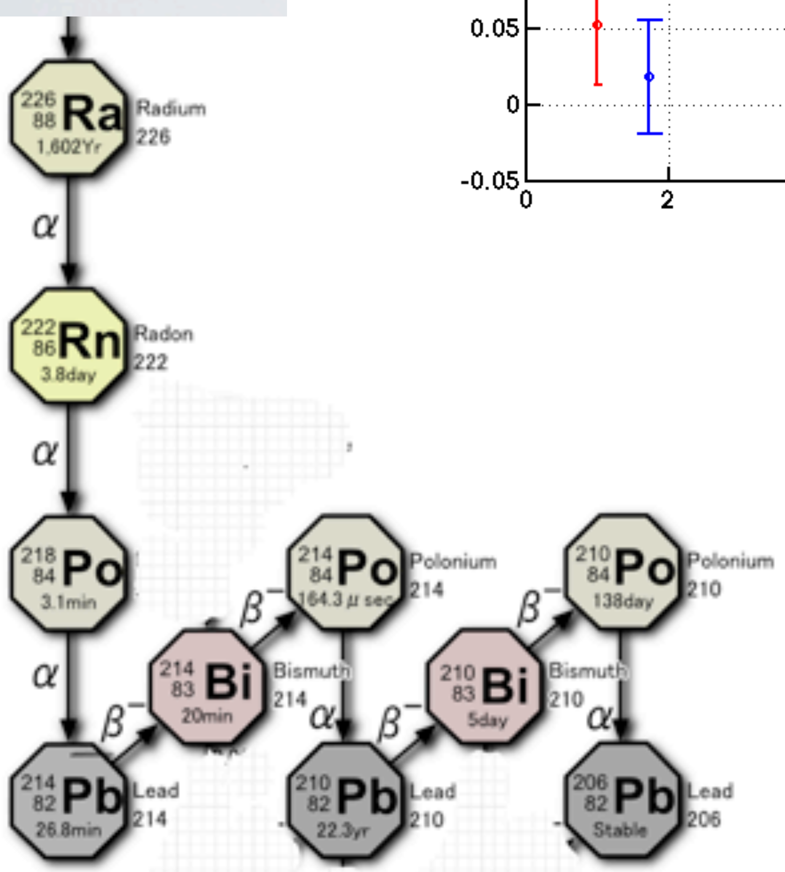




Theory works!
Initial desorption is linear with square root of time.

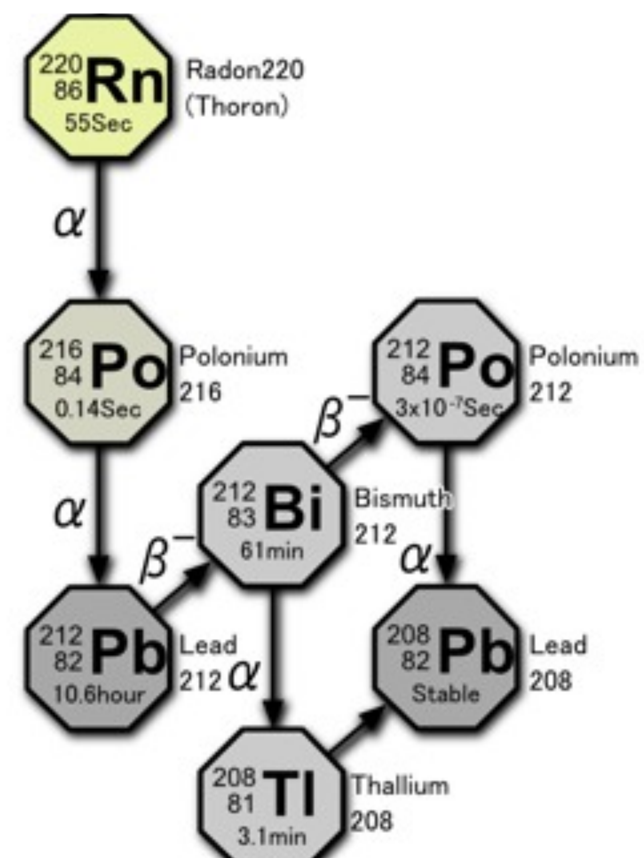
Lead Desorption curves obey $\sqrt{t}$

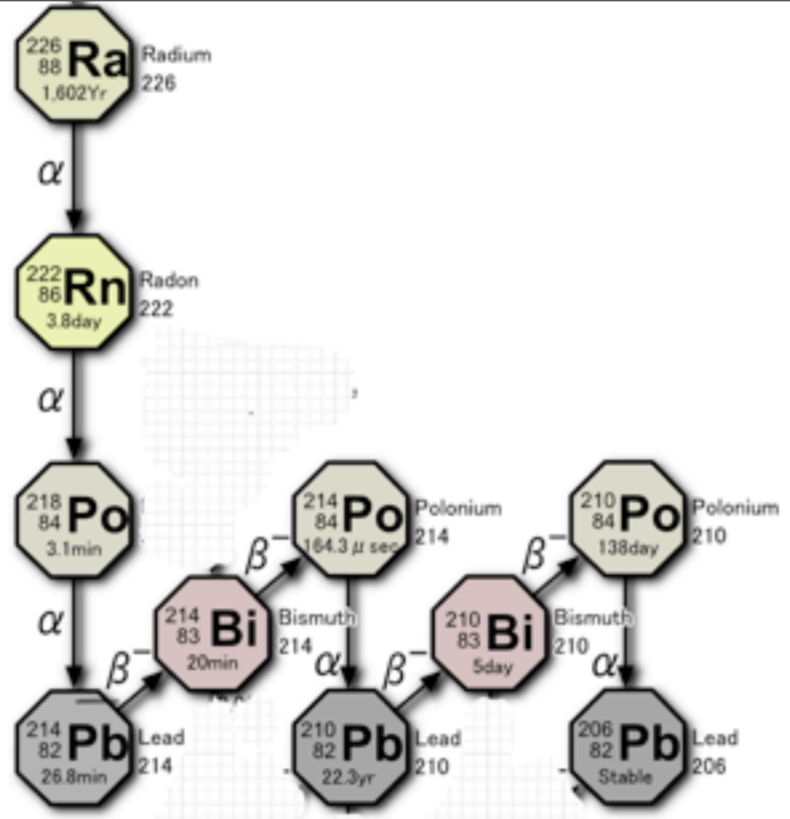




Slope~ 1/L

L~recoils





LEAD-210 IN SNO+ ACRYLIC VESSEL

Sampling of leaching water in AV

- Area of acrylic covered by water 0.88 m2

Po210 counting of surface: 5(1) cpd/cm2

- 12.0 L of UPW for 120 hours (5 days)

Po210 counting of surface: 6(1) cpd/cm2, no change

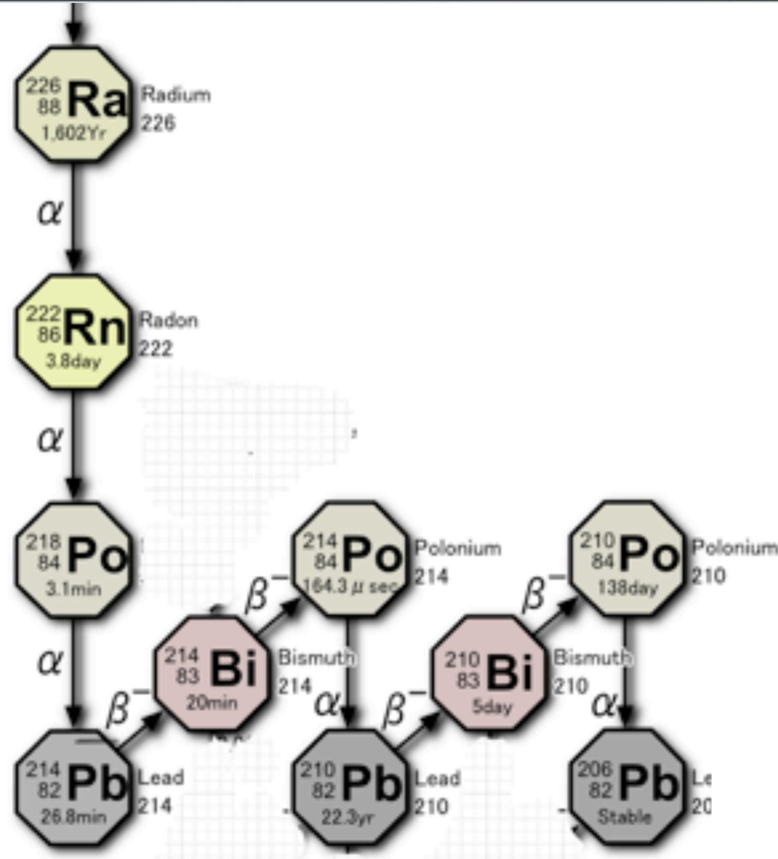
Activity of Po-210 in AV , (33% efficiency):

1.9 Bq/m2,

Po-210 assumed to be in equilibrium with Pb-210

The bottom of the AV was carefully cleaned with a cleaner agent, wiped with paper towels and rinsed with UPW several times. The SNO water plant UPW was poured from the 4 gallon plastic bottle at the AV bottom to cover area with diameter of 105 cm.

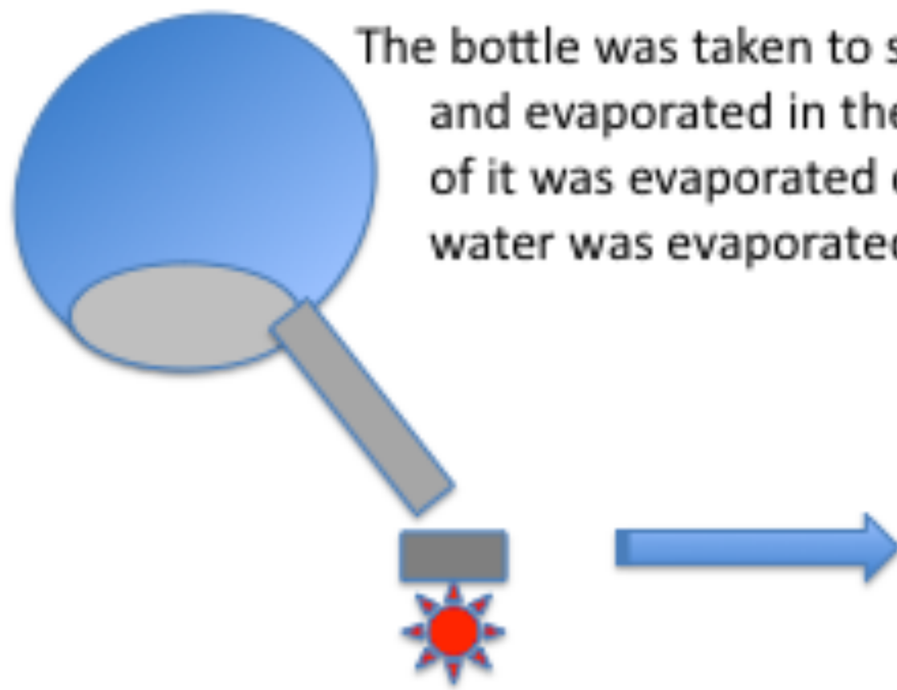
AV Air radon contribution to Pb210 in water sample is estimated: 0.15 mBq



LEAD-210 IN ACRYLIC VESSEL

Pb210 Activity Measurements

The bottle was taken to surface to LU SNO Radio Chemistry Lab and evaporated in the 2 L glass beaker to volume 61 mL, 5 mL of it was evaporated on SS plate for alpha counting. Rest of water was evaporated for gamma counting.



Alpha- Po-210 and
Gamma- Pb-210 counting

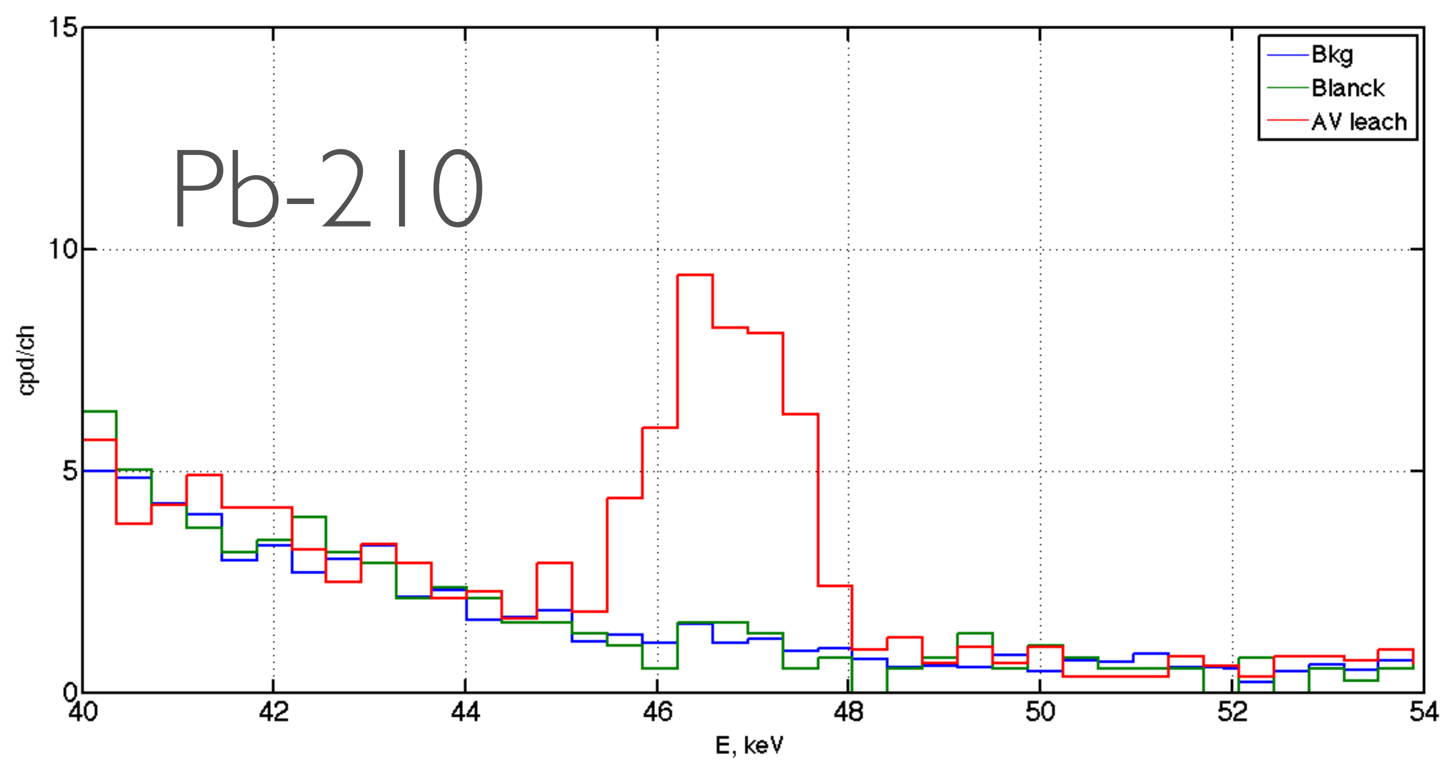
The blank sample was prepared using 8L of water from SNO water plant using same evaporation procedure as for leaching sample. All 8L was evaporated in a 1L beaker with add of few mL of nitric acid. Last 20mL was evaporated on stainless steel plate for gamma counting.

PB-210 IN SNO ACRYLIC VESSEL

$$LR = \frac{16.9\,mBq}{1.9\,Bq/m^2 \times 0.88\,m^2 \times 5\,days} = (2.0 \pm 0.3)10^{-3}day^{-1}$$

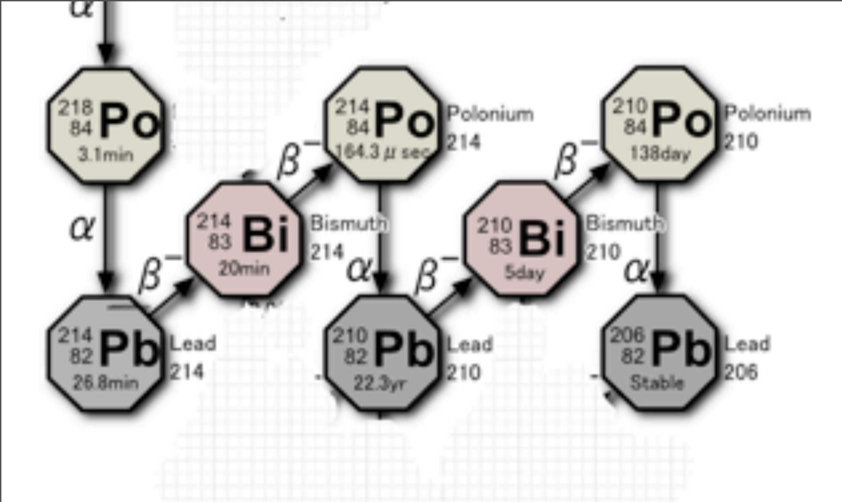
Well-HPGe detector
SNOLAB

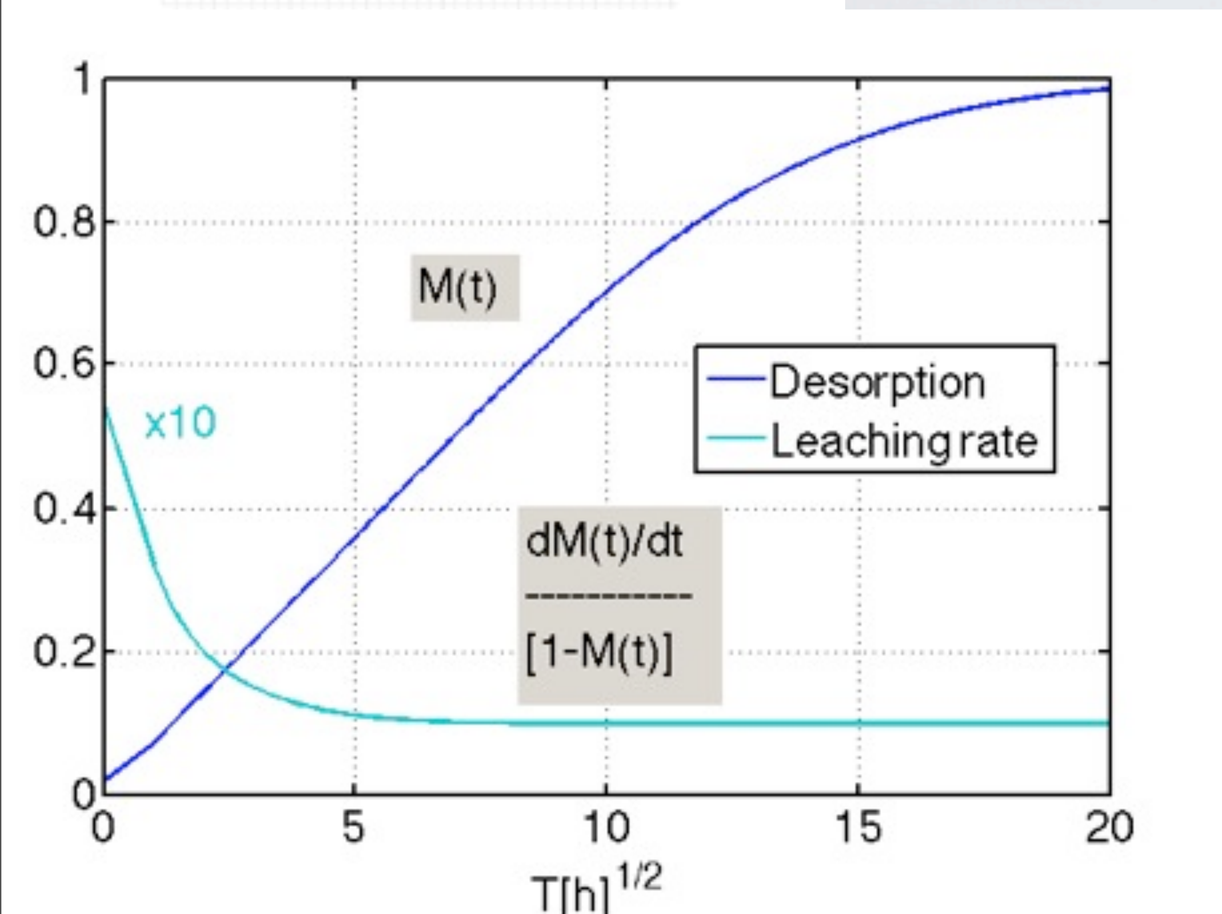
Efficiency ~80%
for
Pb-210 46keV
4.25%

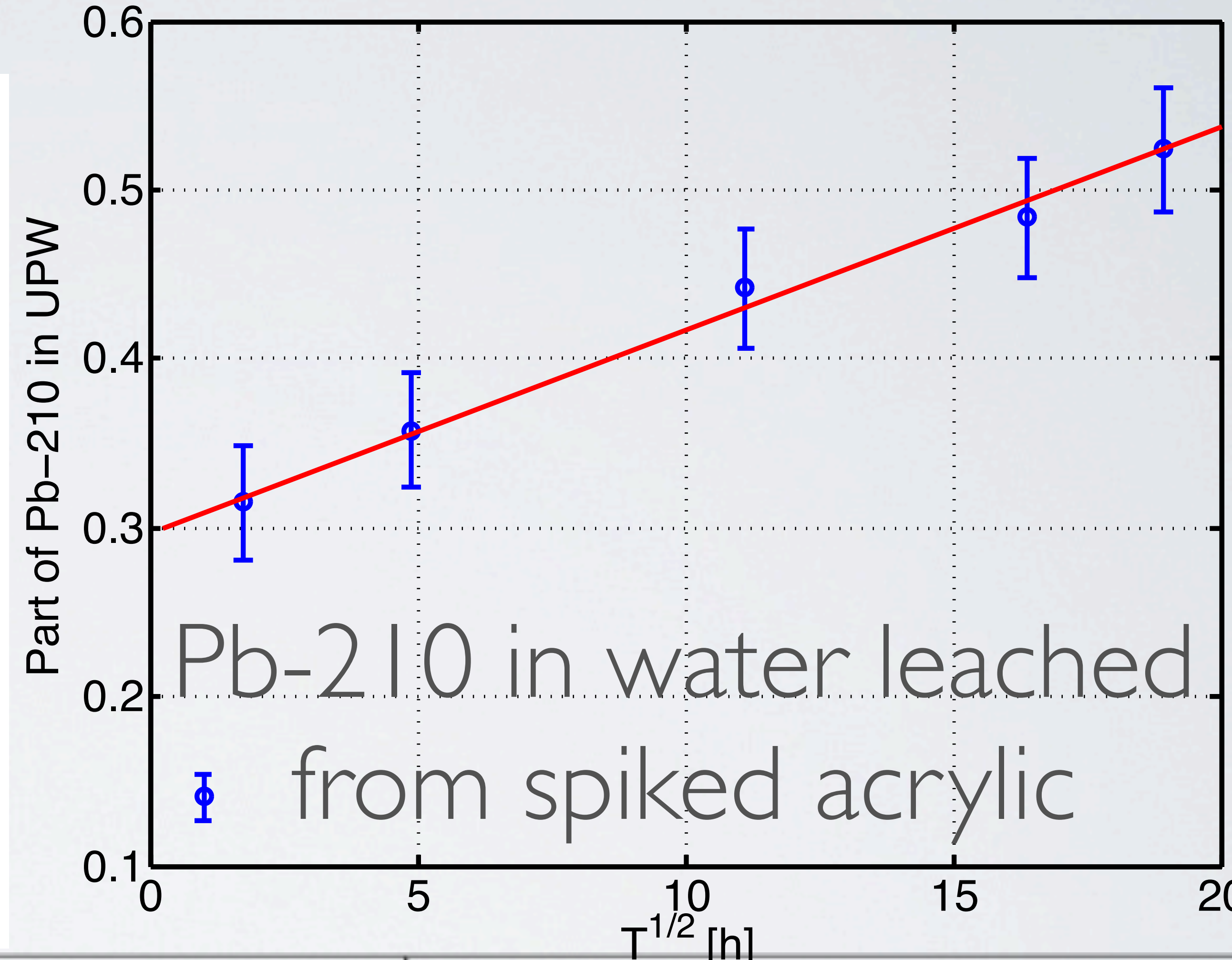


Activity, mBq	Pb-210	Bi-210	Po-210
γ-counting	16.9±1.0	-	-
α-counting	11.8±2.8	-18±98	4.0±2.8

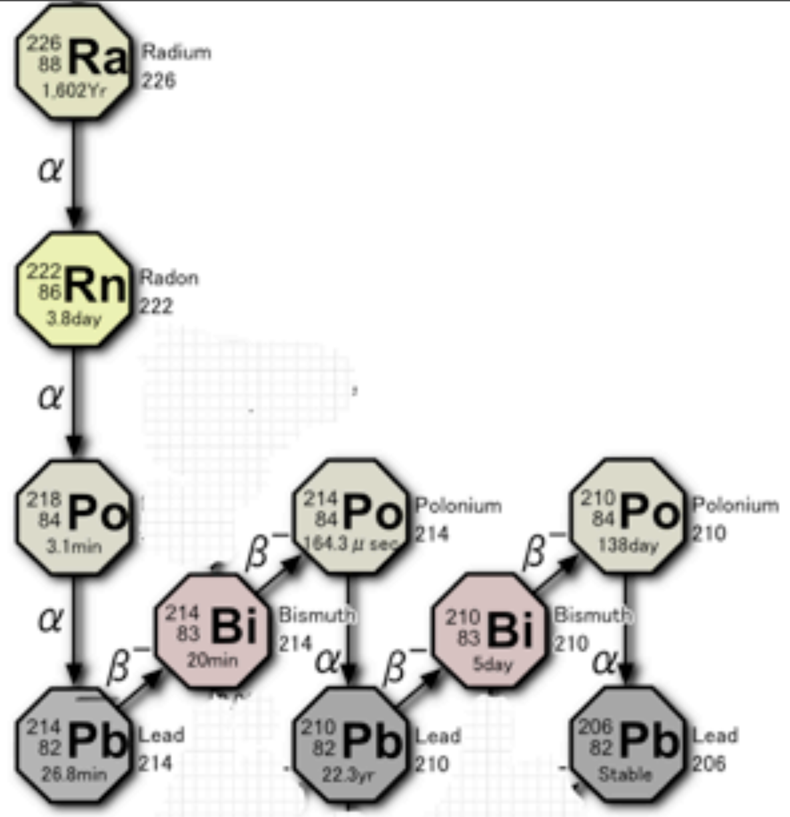
LEAD-210 IN ACRYLIC VESSEL







Slope= $\sqrt{\frac{4D}{\pi L^2}}$,[$\sqrt{1/h}$]		D/L^2,[1/d]	Leaching Rate$_\infty$, [1/d]
Sample	10^{-3}	10^{-3}	10^{-3}
D	8.5 ± 3.3	$1.4\pm^{1.2}_{0.9}$	$3.5\pm^{3.0}_{2.2}$
B	11.8 ± 9.5(*)	$2.6\pm^{6.0}_{2.5}$	$6.5\pm^{14.8}_{6.2}$
AV	Estim.6.6	Estim.0.8	Measur.2.0 ± 0.3



LEAD-210 IN ACRYLIC VESSEL

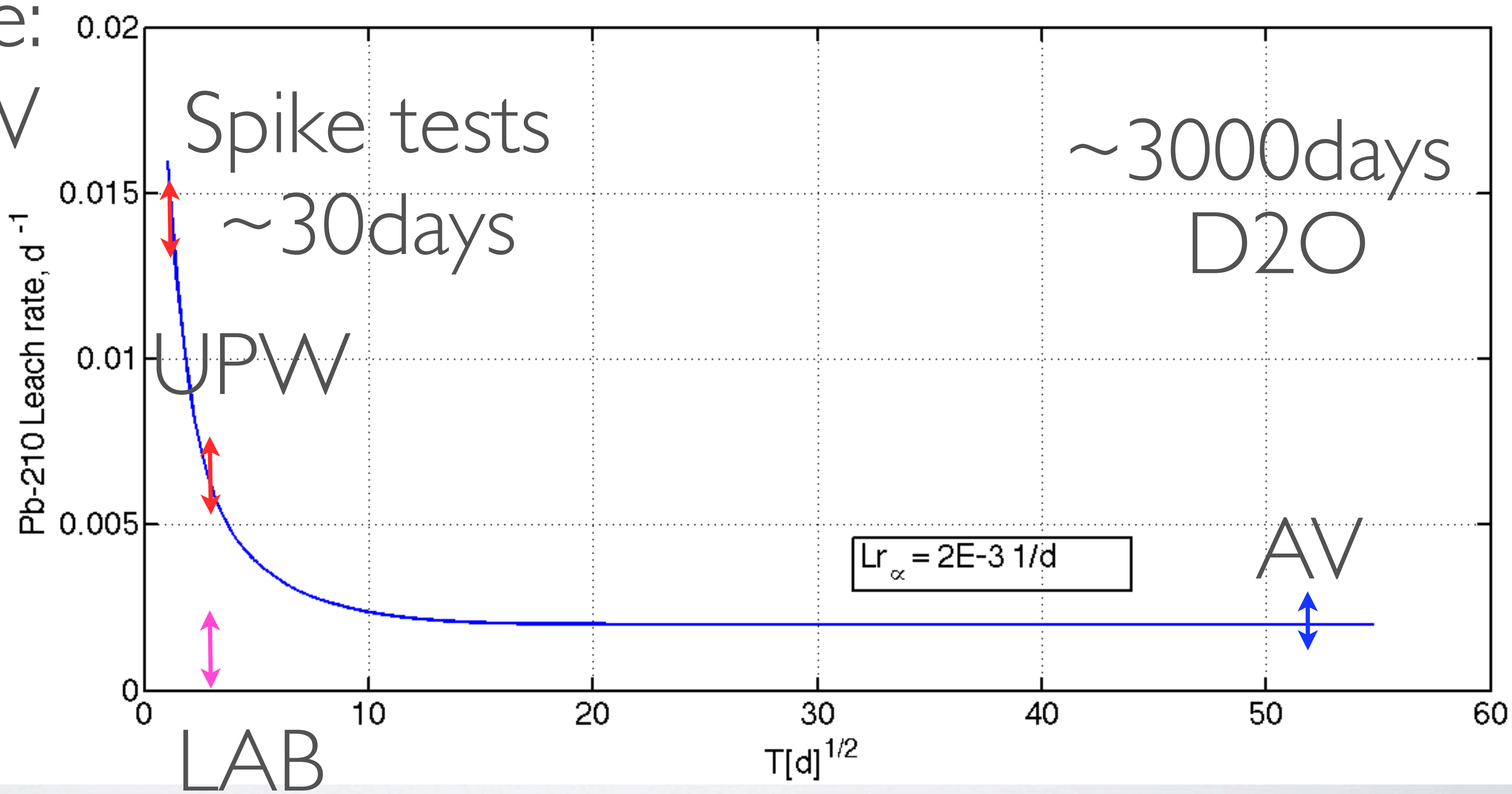
Connecting spike tests of acrylic samples and measurement point in AV

Mean leach time:

~500 days UPW

and

~3000 days LAB



CONCLUSIONS

- Desorption model based on diffusion process works
- Technique of lead leaching tests is developed
- Measurements with spikes can help in process of choice of materials for low background apparatus
- Leaching rates of Lead-210 and Po-210 from SNO acrylic vessel are measured using in-situ samples.
    - Lead-210 is one of major backgrounds in LS detectors: KamLAND, Borexino, SNO+