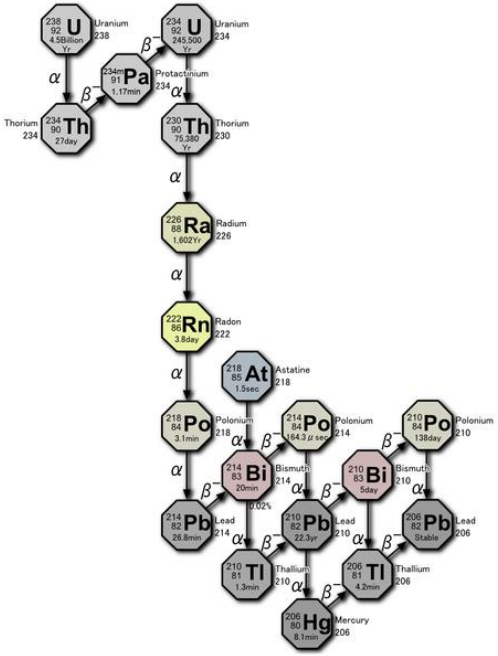
UW Physics 434

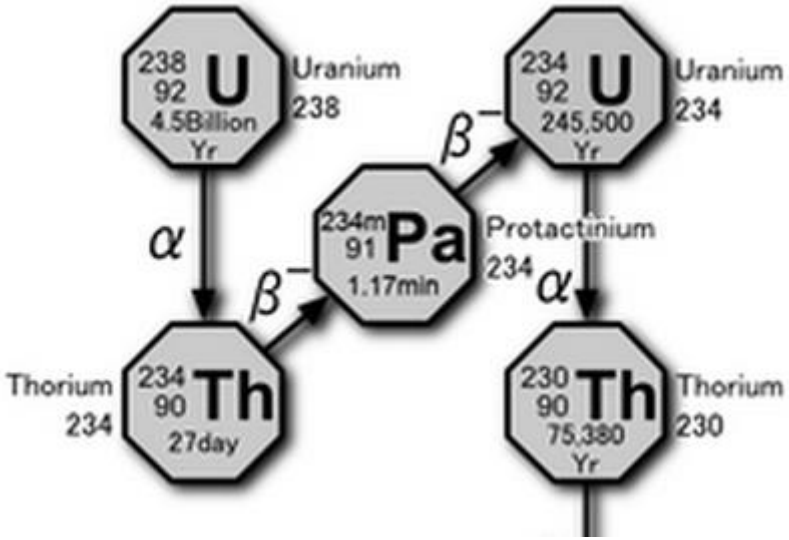
Measure Radiative Decay with the Counter-Timer

References

http://www.nuffieldfoundation.org/practical-physics/measuring-half-life-protactinium
http://en.wikipedia.org/wiki/Methylisobutylketone
http://en.wikipedia.org/wiki/Liquid-liquid_extraction
http://en.wikipedia.org/wiki/Uranium-238
http://en.wikipedia.org/wiki/Meta_state
http://en.wikipedia.org/wiki/Geiger_counter

“Radium” Decay Series of ^{238}U





Nuclide		Historic name	Decay mode	Half-life	MeV	Decay product
^{238}U		Uranium	α	$4.468 \cdot 10^9$ a	4.270	^{234}Th
^{234}Th		Uranium X1	β^-	24.10 d	0.273	^{234m}Pa
^{234m}Pa		Uranium X2	β^- 99.84% IT 0.16%	1.16 min	**2.271** 0.074	^{234}U ^{234}Pa

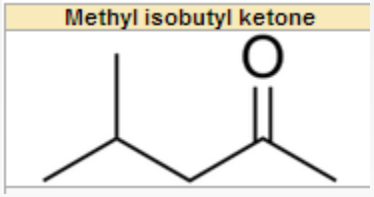
Rates: Production and Decay

- Our samples have about 1 g of ^{238}U dissolved in water
- We will measure the β-decay rate of the daughter ^{234m}Pa$\rightarrow$e$^-$ + ^{234}U by detecting the electron (β^- particle) in a Geiger counter.
- Production rate: $\frac{1}{238}\,(6\times10^{23})\frac{1}{2\times10^{17}s}\approx 13\times10^{3}s^{-1}$
  (note: mean lifetime is half-life/ln(2))
- ^{234m}Pa mean lifetime: $\tau = \frac{1.16}{0.683}\text{min}\times 60\frac{\text{s}}{\text{min}} = 100\text{s}$
  - So equilibrium number is ~1.3M
- Number vs. time: $N(t) = N_0\exp(-t/\tau)$
- Beta decay rate (what we measure)
  $R(t) = R_0\exp\left(-\frac{t}{\tau}\right) + \text{B}$
  - Where R_0 is the initial rate, N_0/τ times efficiency, and B is a background rate.

The Chemistry: Extracting Protactinium

From the Wikipedia article:

> **Liquid–liquid extraction** also known as **solvent extraction** and **partitioning**, is a method to separate compounds based on their relative solubilities in two different immiscible liquids, usually water and an organic solvent. It is an extraction of a substance from one liquid into another liquid phase. Liquid–liquid extraction is a basic technique in chemical laboratories.

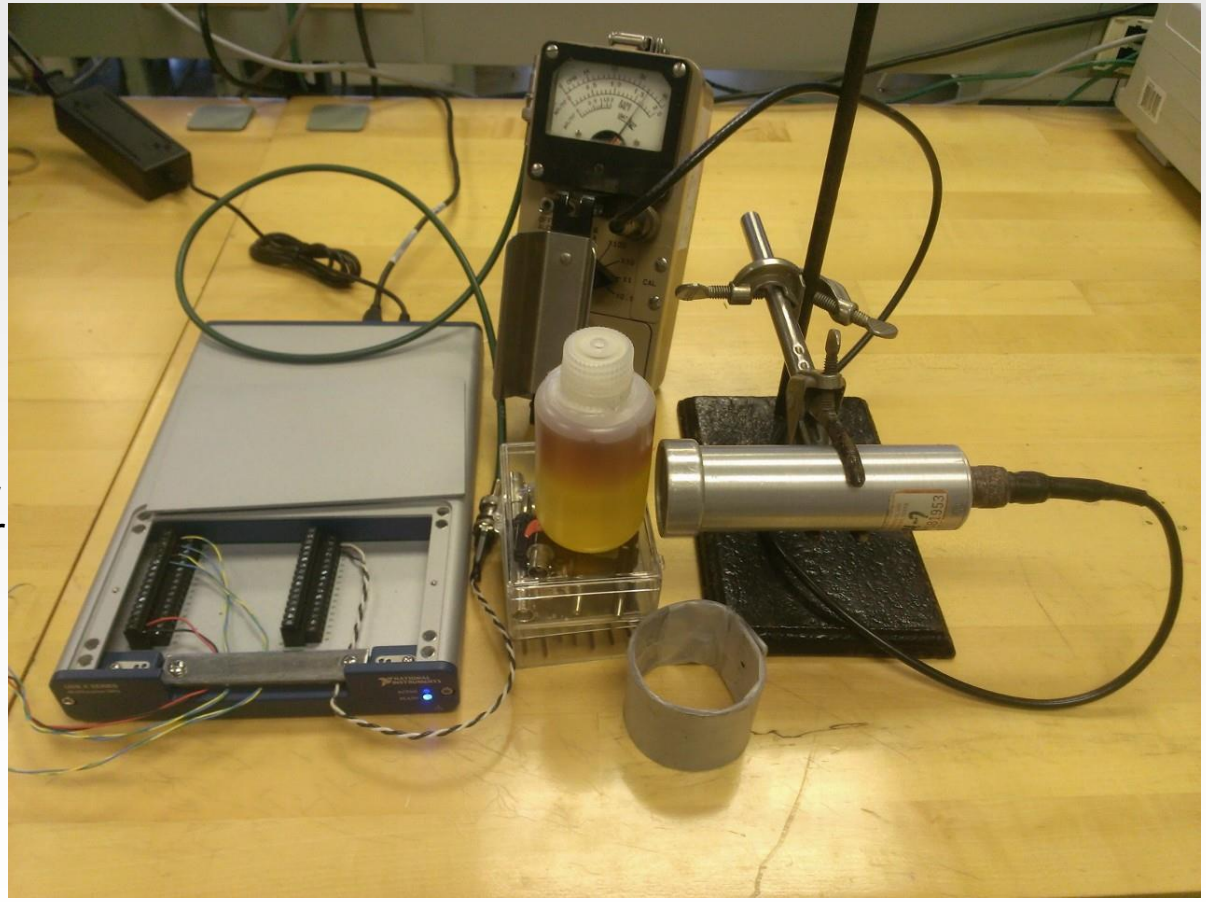


In our case: water and methyl isobutyl ketone, $C_6H_{12}O$.
Density: 0.8, not soluble in water.
Pa soluble in it; U in water
Procedure:

- Shake up for ~30 sec: some of the Pa in the water dissolves in it
- Wait until separates, no longer than 30 sec.
- Shield the G-M tube from water with lead ring, take data for 5 min or so

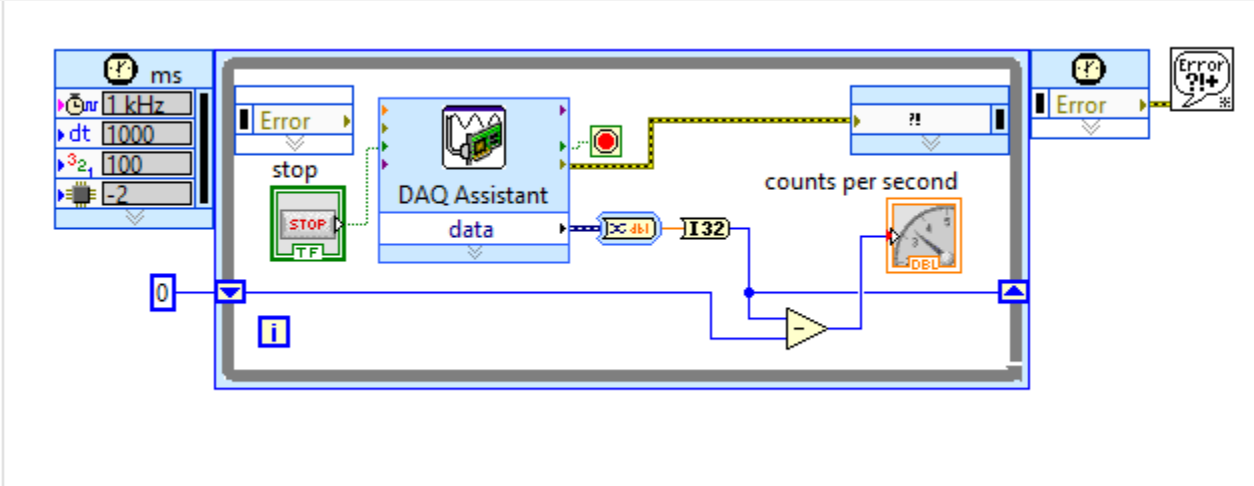
Experimental Setup

- Use ctr0 – PFI 8/PFI 9 – wire to white/black twisted pair to BNC
- Geiger counter set to x1 when in use, OFF otherwise
- Point G-M tube to water for constant experiment, ketone with Pb shield for decay experiment



Data Acquisition

- A timed loop, default 1s interval
- DAQ Assistant uses ctr0 in count edges mode, 1 sample on demand
- Uses a shift register to obtain the counts per interval
- Stop button passed into the VI to release hardware
- Error handling: stops loop, generates dialog box



VI: You Need To

- Add controls, and logic to:
  - adjust the time increment
  - set a total time
- Acquire an array of the counts per interval:
  - display it in a graph
  - write it to a disk file.

Procedure

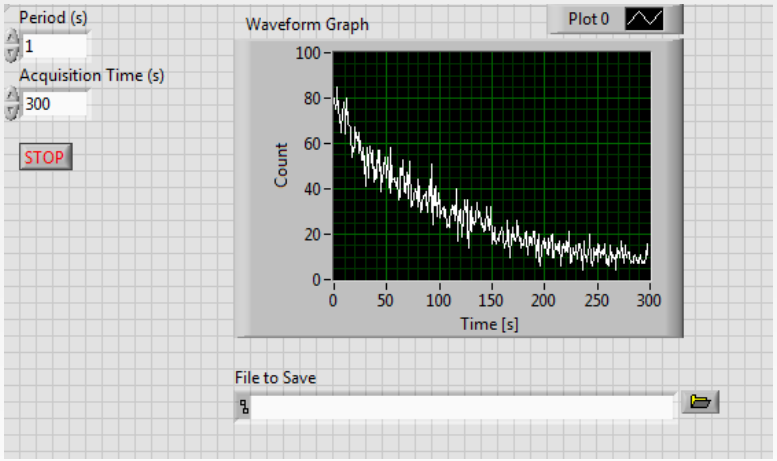
- Calibrate
  - Use your pulse generator, set to 100 Hz, as measured by the oscilloscope, and verify that you measure it within 1%
- Constant rate data
  - Take 1 or 2 min pointing at the water before shaking, save to disk
- Decay rate data
  - Shake up as described above, point the G-M tube at the ketone, take 5 min and save into a different file

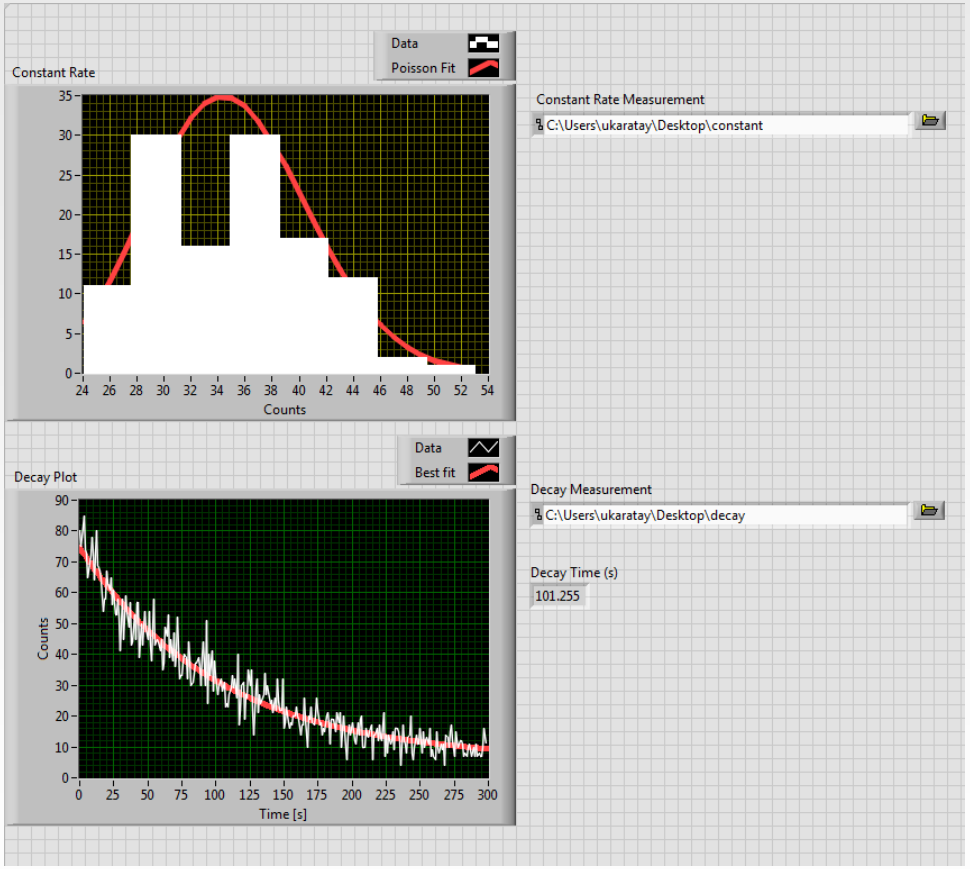
Remember to switch the Geiger counter off when not in use!

Analysis

- In a separate VI or VIs:
  1. Draw the decay data with an exponential overlay (fit).
  2. Make a histogram of the counts for the constant run and check to see if it obeys the Poisson distribution by overlaying the function. Note that you will probably want to discard the first few points.
- Submit all 2 or 3 in a project file.

Sample UIs


Period (s)
1
Acquisition Time (s)
300
STOP
Waveform Graph
Plot 0
Count
Time [s]
File to Save


Data
Poisson Fit
Constant Rate
Counts
Constant Rate Measurement
C:\Users\ukaratay\Desktop\constant
Data
Best fit
Decay Plot
Counts
Time [s]
Decay Measurement
C:\Users\ukaratay\Desktop\decay
Decay Time (s)
101.255