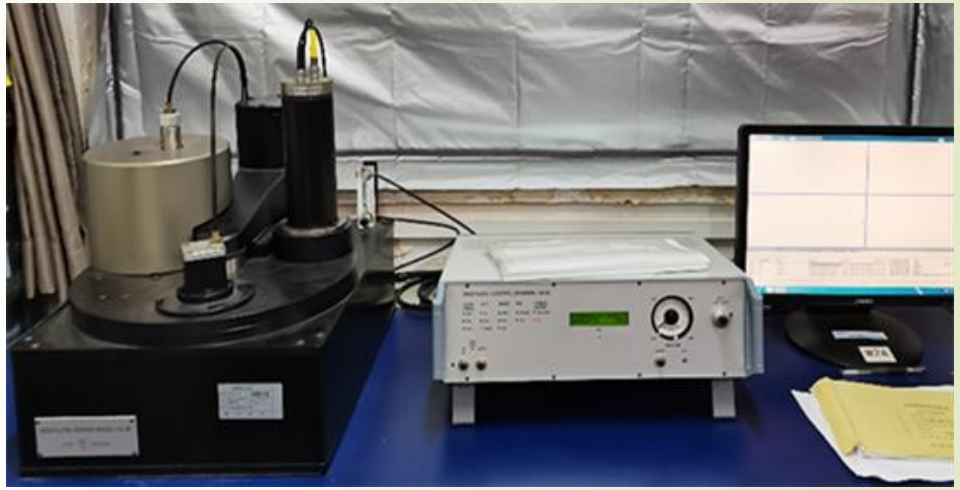
Thermoluminescence and Optically Stimulated Luminescence

Archeological Chemistry Seminar

2023 AAS/ARAS Training Program

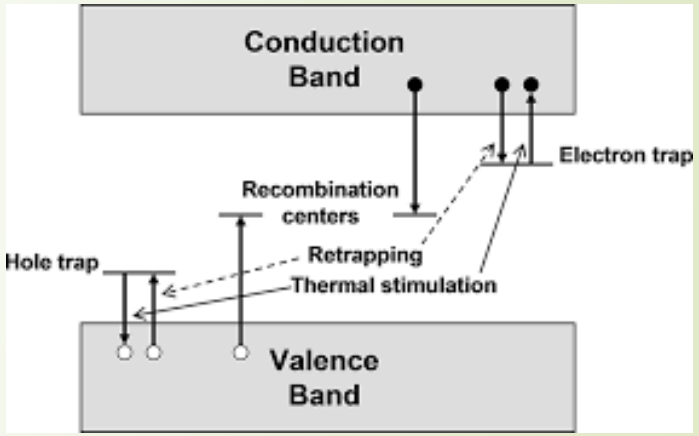
Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL)

- Thermoluminescence was developed in the 1950s and 1960s
  - Primarily by Martin Aitken at the University of Oxford
  - Uses heat to release light
  - Used to date the age of ceramics
- Optically Stimulated Luminescence developed in 1980s and 1990s
  - Uses lasers or LEDs to release light
  - Used to date ceramics and buried soil layers



How TL works

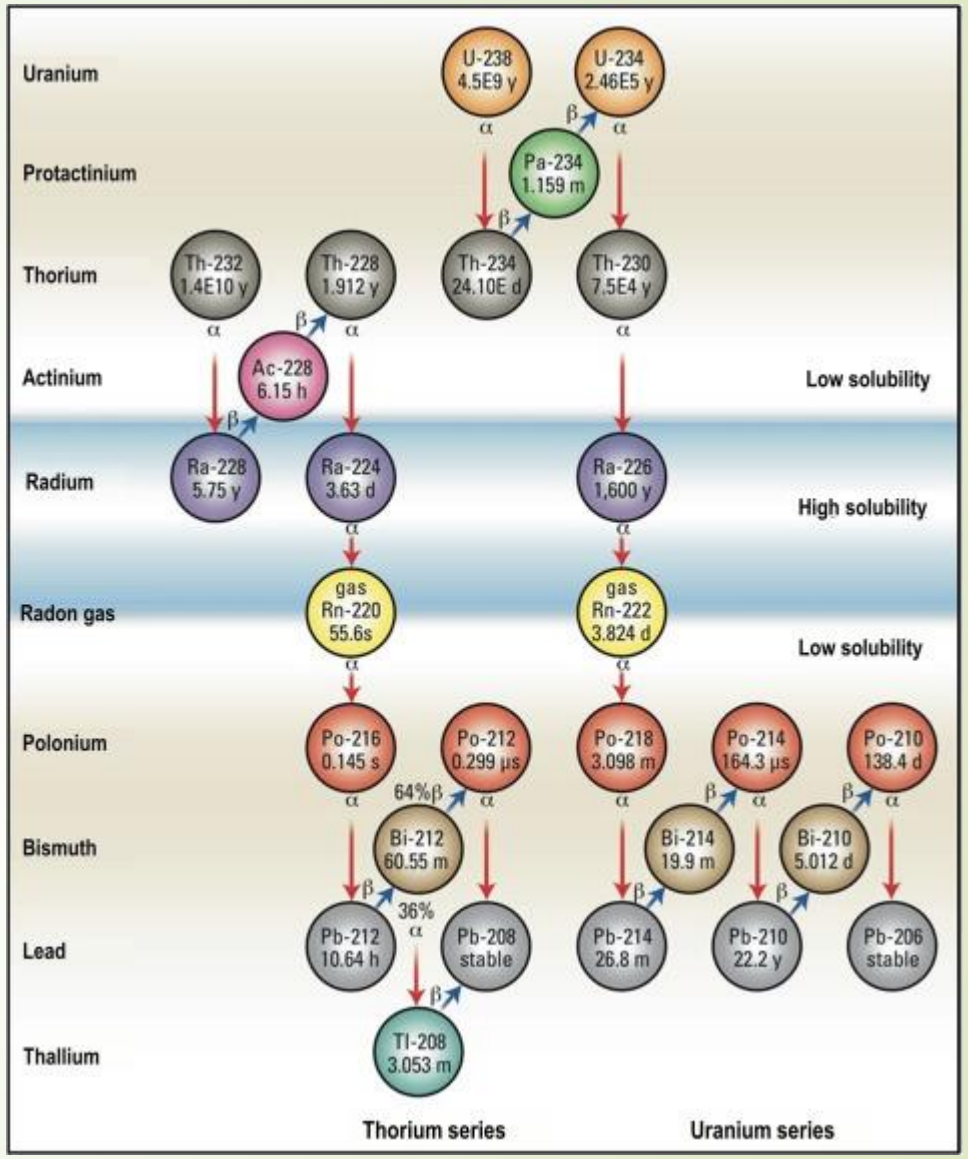
- Certain minerals (common in clays) can absorb naturally occurring radiation (mainly gamma rays)
  - Mainly quartz and feldspar minerals
  - Electrons are excited to higher energy states
  - A small fraction get trapped in crystal defects of the mineral known as "electron traps"
  - These traps are stable for thousands of years
  - Excitation of the mineral (heat, light, pressure…) causes the electrons to return to their ground state
- Thus, the amount of light given off by the sample during excitation is proportional to the age of the ceramic
- TL measures the time elapsed since the ceramic was last heated to ~300+°C



What causes TL?

- Naturally occurring soil radionuclides create TL by excitation of electrons with gamma rays
- U-238 $t_{1/2}$ = 4.5 billion years
- U-235 $t_{1/2}$ = 704 million years
- Th-232 $t_{1/2}$ = 14.1 billion years
- K-40 $t_{1/2}$ = 1.3 billion years

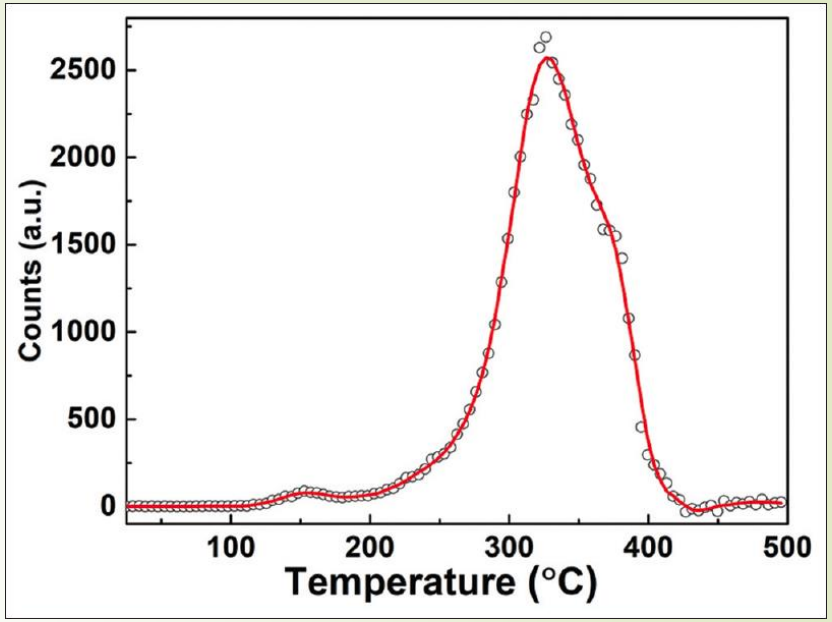
To determine a TL age of pottery, these isotopes must be measured either in the field or in the pottery.

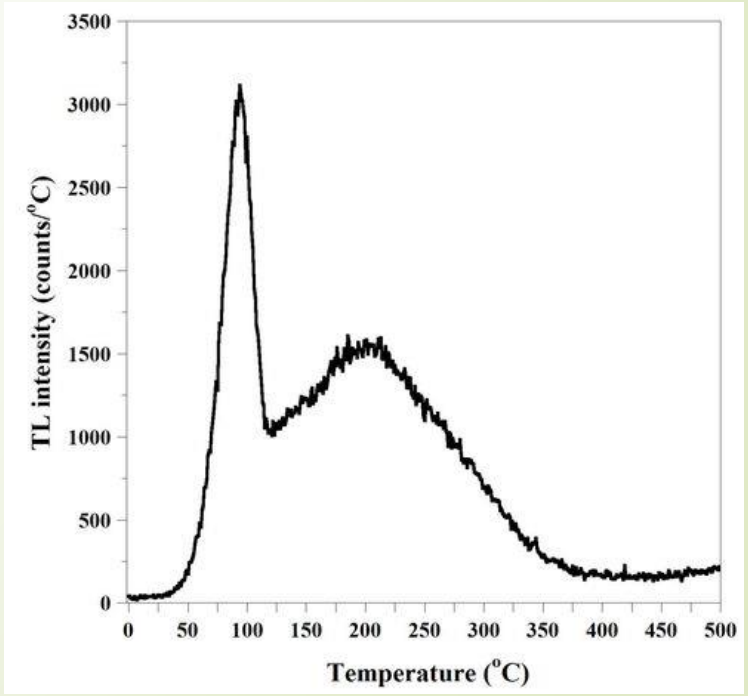


Decay chain of U-238

How TL samples are prepared

- Ceramic pieces are weighed and then dried in a low-temperature oven for several days to remove moisture. Then weighed again.
- Ceramic is then ground to a fine powder and sifted through fine mesh screens.
  - Typically, grain sizes are <100 microns
- Powdered samples are placed inside chamber with heating strip underneath
- Photomultiplier tube (to measure light given off) is placed directly above the sample.
- Heating strip is ramped from 0-500°C over about 30 seconds.
  - Light given off at each temperature is recorded
- TL sensitivity to radiation is measured on same sample, by exposing the sample to a known dose of radiation and then measuring TL again





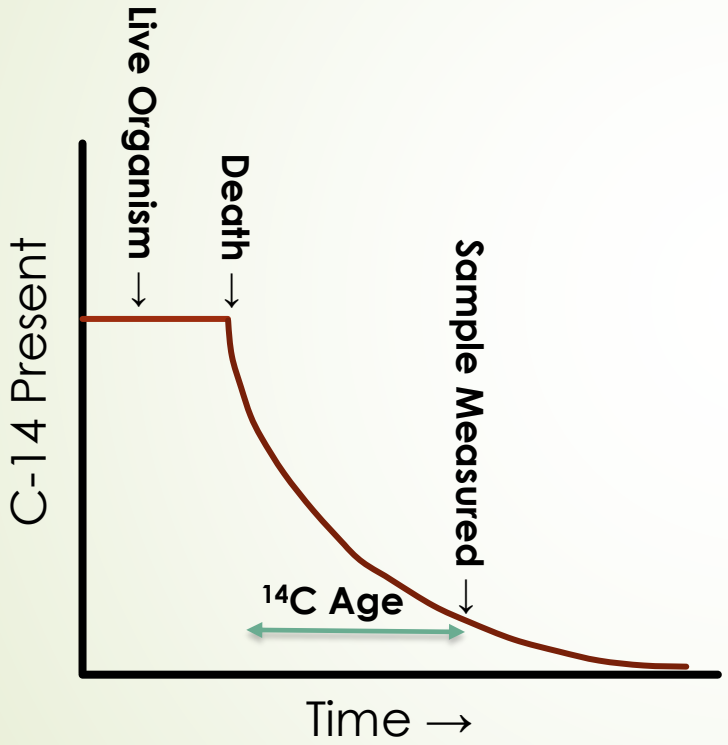
Calculating TL (or OSL) age

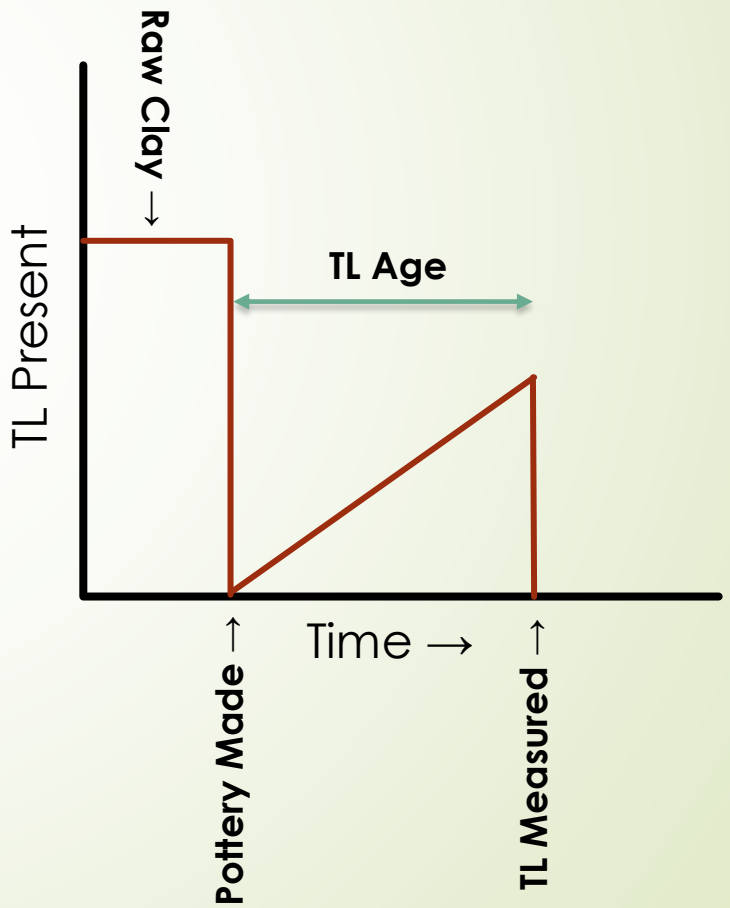
Determined from natural TL

TL age = (total absorbed radiation dose)/(radiation dose rate)

Determined from induced TL and surrounding environmental radionuclide concentrations

Comparison between C-14 and TL Dating





Optically Stimulated Luminescence (OSL)

- Very similar to TL
- Primary difference is luminescence is stimulated by light rather than heat
  - Optical lasers
  - LED
  - Infrared lasers
- Can be used to date buried soil surfaces.
  - Determines when the soil was last exposed to light

Image References

Page #

2 https://www.scirp.org/journal/paperinformation.aspx?paperid=119204

3 https://www.amity.edu/gwalior/journal/papers/etjri_v2_isse_1_03.pdf

4 https://www.fysik.dtu.dk/english/research/radphys/research/radiation-instruments/tl_osl_reader

5 https://rpe.org.in/article.asp?issn=0972-0464;year=2023;volume=46;issue=5;spage=163;epage=229;aulast=;type=36

6 https://archaeologydataservice.ac.uk/help-guidance/guides-to-good-practice/case-studies/project-specific-guides/thermoluminescence-dating/