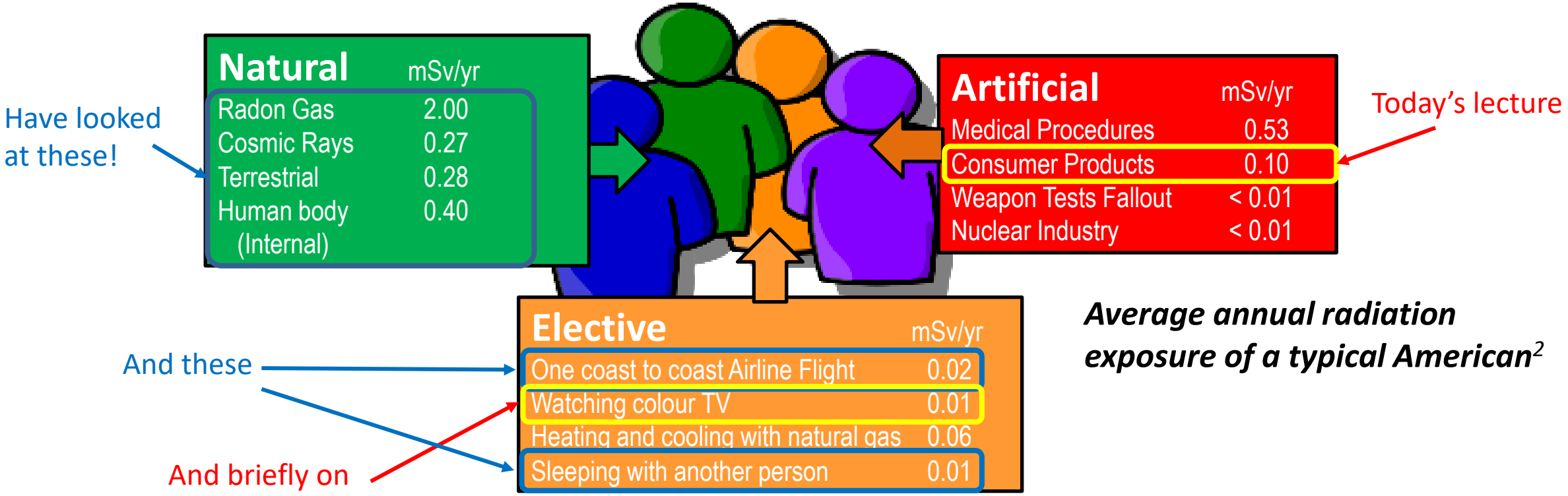
GET1024 / GEC1036 Lecture 7

Radiation in the Everyday Life

- Items with Elevated Activity
- (Mis)uses in Early 1900s
- Radioluminescence
  - Radium
  - Tritium
- Items with High Activity
  - Fiestaware
  - Old Lenses
  - Gas Mantles
  - Smoke Detectors
  - Lightning Rods
- TV Screens (?)

Radiation is a Fact of Life

Exposure to radiation from natural sources is an ***inescapable*** feature of everyday life in both working and public environments. This exposure is <u>in most cases</u> ***of little or no concern to society***, but in certain situations the introduction of <u>health protection measures</u> needs to be considered, for example when working with uranium and thorium ores and other **n**aturally **o**ccurring **r**adioactive **m**aterial (NORM)." – IAEA [1]



Average annual radiation exposure of a typical American[2]

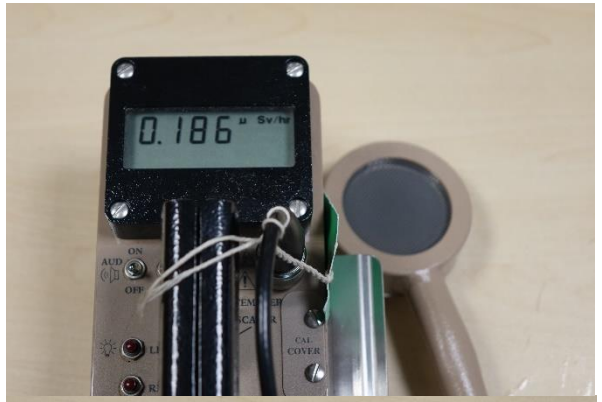
[1] http://www-ns.iaea.org/tech-areas/rw-ppss/exposure-to-natural-radiation.asp?s=3

[2] Radiation and Modern Life – Alan E. Waltar

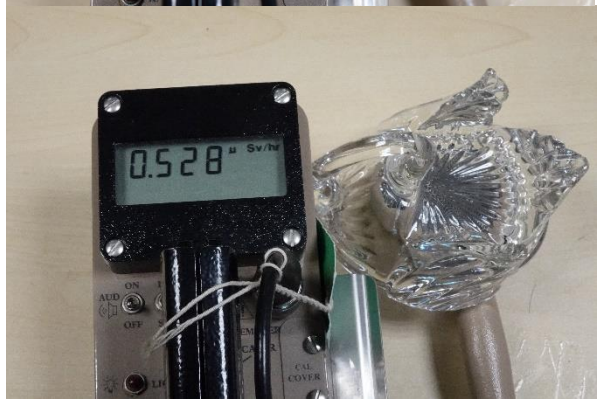
Objects with Elevated Radiation

- Some man-made objects / materials that we handled in our normal life contains radioactive nuclides of higher concentration than the overall average concentration in natural objects.
- When a GM counter is placed on its surface, it could read a value that is above the background reading (usually 2 – 3 times higher).
- Below are some examples of these objects:

Background



Decorative glass piece



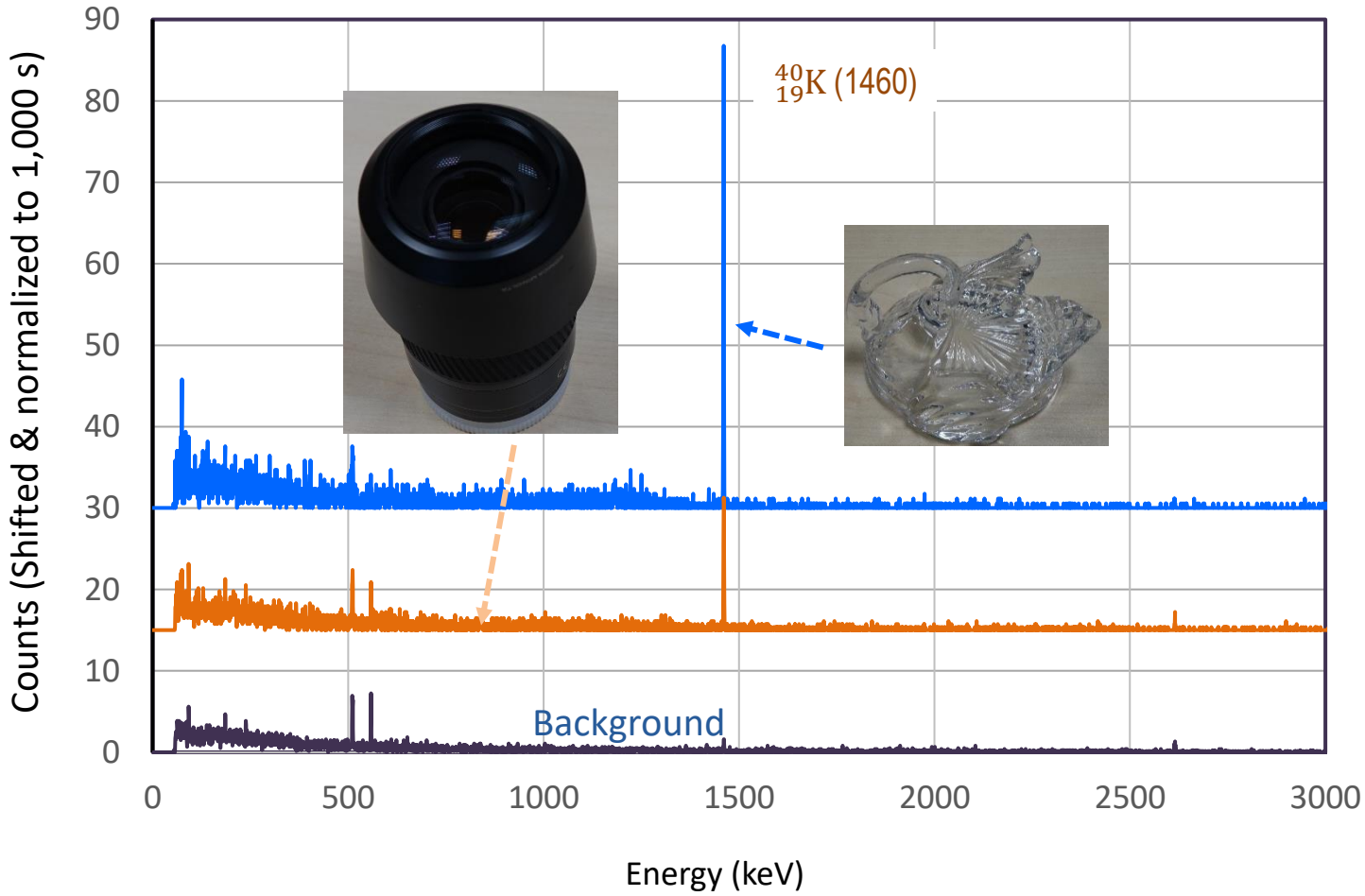
Pottery

Ordinary camera lens

Potassium-40 in Glass

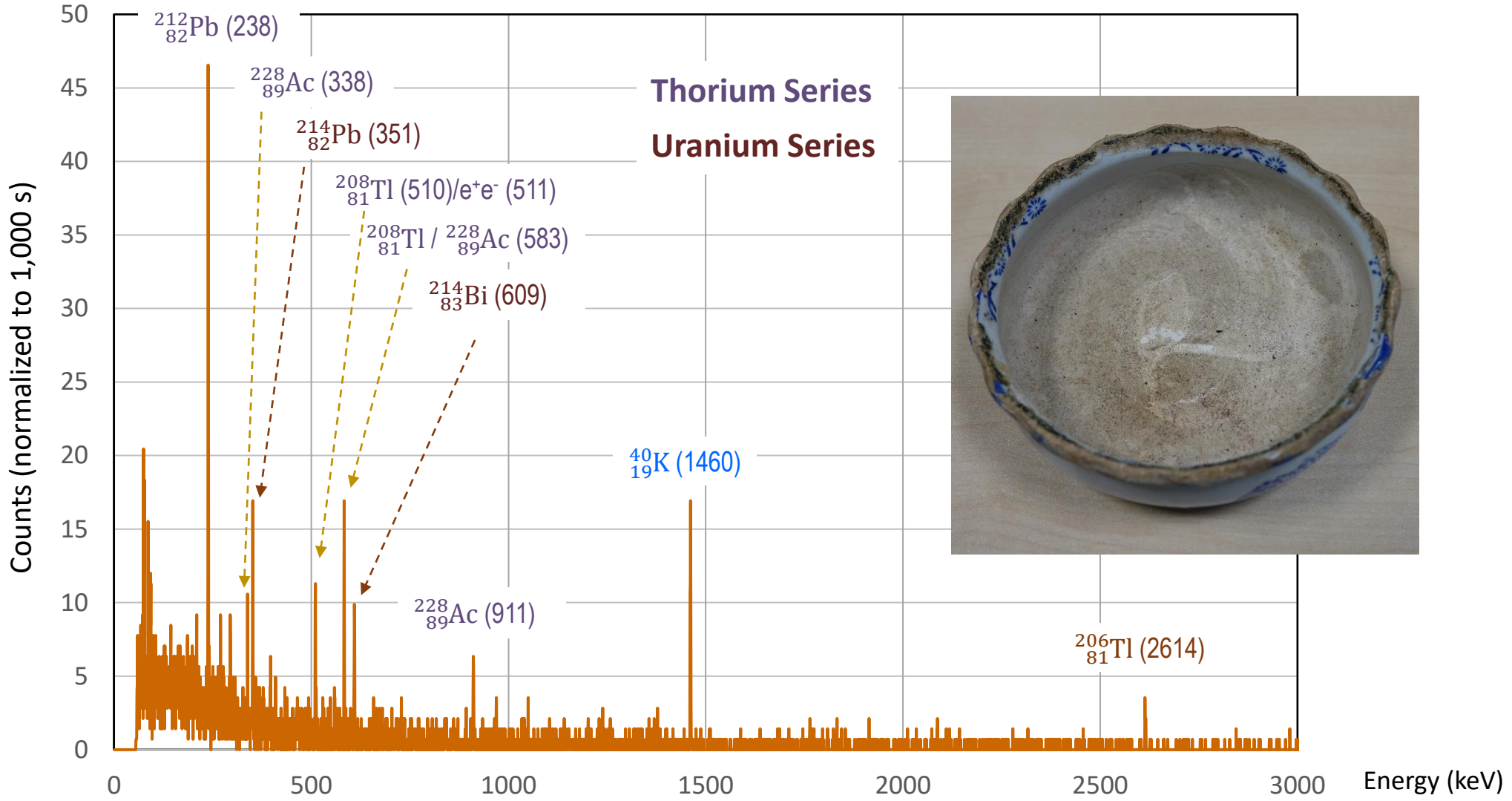
- Glass pieces (lens, decorative pieces) can have an elevated count over background due to presence of K-40.
- In fact when we measure the activity of K-40 and do spectroscopy of food items, they should not be placed in glass container or we would need to measure the container separately to subtract it off.

Below are the gamma spectra obtained from the camera lens and decorative pieces.



Pottery

- Many man-make materials such as pottery can contain slightly higher level of uranium and thorium as can be seen in the gamma spectrum below.



“Radioactive” Objects

- Almost every object made from natural materials contains some amount of radioactivity.
- The examples in the last few slides contain higher than the average level and thus can be picked up if one uses a sensitive device to look for them. Are these considered to be radioactive?
- Walls, floorings or countertops containing granite often show elevated level of radioactivity too due to higher level of potassium and uranium (10 – 20 ppm). Concerns over radiation from granite countertops and radon coming out of them were found to be unfounded (way below background level).[1]
- Another class of objects that one may encounter in everyday life contain even higher level of radioactivity because some parts of the objects are made from radioactive elements such as uranium, thorium or radium or may contain small radioactive source such as americium.
- Due to greater awareness of danger of ionizing radiation and stricter regulations, most of them are now not easily available to general public. We will study some of these in the next few slides.

[1] https://en.wikipedia.org/wiki/Granite

“Uses” of Radioactive Materials in Early 1900s

- In the first half of the 20th century, radium is used for many products and “cures” for various health problems.

"Tho-radia" powder, based on radium and thorium[1]

Advertisement for a “scientifically” developed radiation emanation activator.[1]

Radioactive toothpaste (thorium) advertised to kill bacteria and whiter teeth [2]

RADIUM THERAPY

The only scientific apparatus for the preparation of radio-active water in the hospital or in the patient's own home.

This apparatus gives a high and measured dosage of radio-active drinking water for the treatment of gout, rheumatism, arthritis, neuralgia, sciatica, tabes dorsalis, catarrh of the antrum and frontal sinus, arterio-sclerosis, diabetes and glycosuria, and nephritis, as described in Dr. Saubermann's lecture before the Roentgen Society, printed in this number of the "Archives."

DESCRIPTION.

The perforated earthenware "activator" in the glass jar contains an insoluble preparation impregnated with radium. It continuously emits radium emanation at a fixed rate, and keeps the water in the jar always charged to a fixed and measureable strength, from 5,000 to 10,000 Maché units per litre per diem.

SUPPLIED BY
RADIUM LIMITED,
93, MORTIMER STREET, LONDON, W.

[1] https://en.wikipedia.org/wiki/History_of_radiation_therapy

[2] http://awesci.com/radioactive-toothpaste-shocking-ad-50s/

[3] http://funeralfund.blogspot.sg/2014/03/mae-keane-believed-to-be-last-of.html

Radium

- Radium (Ra) was discovered by Marie and Pierre Curie in Dec 1898.
- Atomic number: 88.
- Naturally occurring Isotopes:
  - ^{223}Ra (half-life 11.4 days – ^{235}U decay chain),
  - ^{224}Ra (3.64 days – ^{232}Th decay chain),
  - ^{226}Ra (1600 years – ^{238}U decay chain), and
  - ^{228}Ra (5.75 years – ^{232}Th decay chain).

- **^{226}Ra** is the most stable form of radium and makes up most of the natural radium.
- About 2.7 million times more radioactive than the same mass of natural uranium (mostly uranium-238) due to its proportionally short half-life. (1 g → 1 Ci)
- ^{226}Ra emits mainly alpha particles, and its decay products emit alpha, beta particles, most of which with gamma emissions too.

https://en.wikipedia.org/wiki/Radium

Radioluminescence

- **Radioluminescence** is the phenomenon by which light is produced in a material by bombardment with ionizing radiation such as alpha particles, beta particles, or gamma rays.[1]
- It can be used as a low-level light source for night illumination of instruments or signage or other applications where light must be produced for long periods without external energy sources.
- **Radium** (mixed with a phosphor such as zinc sulphide ZnS) has been used on clock and watch faces and instrument dials to make them visible in the dark since 1908 and continued to be used until 1960s when it was replaced with the other radioisotopes due to health concerns.

1 https://en.wikipedia.org/wiki/Radioluminescence

Radium Girls

- The Radium Girls – female factory workers who contracted radiation poisoning from painting watch dials with self-luminous paint containing radium at 3 different factories in US beginning around 1917 into the 1920s.

Workers were told they could paint faster if they dipped their brushes into the radium-laden paint and then sharpened the bristles with their lips. They were assured that the procedure was safe. Some workers even painted their nails and lips.

Women working at a factory of the United States Radium Corporation, 1922

- Many fell dangerously sick and died. In court cases that followed, even shown that radon was found in their breaths. Resulted in regulations enhancing industrial safety standards. Radium dial painters were instructed in proper safety precautions and provided with protective gear.

From https://en.wikipedia.org/wiki/Radium_Girls

Radioluminescence (2)

- Beside the court case of the Radium Girls, scientists have also shown that the dose is high and is of concern, especially if taken out of its original casing or ingested.
- Replaced by Promethium (2nd half of 20th century), then tritium.

https://deltagearinc.com/navigation/compasses/cammenga-compass-tritium.php

http://gunbelts.com/blog/a-quick-guide-to-night-sights/

Isotope	Half-life (yrs)	Main decay mode	Remarks
Radium (Ra-226)	1600	Alpha with gamma	Highly radioactive, produces radon
Promethium (Pm-147)	2.62	Beta – low energy	Needs to be replaced frequently. Decays quickly so that waste is not an issue.
Tritium (H-3)	12.3	Beta – low energy	Gaseous – need to be encased

Tritium

- Half-life = 12.3 years
- Beta decay: ${}^{3}_{1}\mathrm{T} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{0}_{-1}e^{-} + \bar{\nu}_e$ (Tritium is a special isotope of hydrogen so that it has its own name and one may write ${}^{3}_{1}\mathrm{T}$ instead of ${}^{3}_{1}\mathrm{H}$.)
- Max beta energy = 18.6 keV (average = 5.7 keV) - very low compared to any other sources!
- Beta particles from tritium can penetrate only about 6.0 mm of air, and they are incapable of passing through the dead outermost layer of human skin. Considered to be quite safe so long as the casing is not broken.
- Dose is estimated to be 0.64 mSv per mCi ingested.
- Tritium has been used in many emergency exit signs – no need for power and can last for up to 10 – 20 yrs.
- Note that in terms of activity, the tritium that is used has very high level compared to other materials, e.g., a gun-sight contains about 12 mCi of tritium and an exit sign can contain up to 20 Ci of tritium!

https://nrcpublicblog.files.wordpress.com/2015/02/exit3.jpg

https://en.wikipedia.org/wiki/Tritium

http://www.physics.isu.edu/radinf/tritium.htm

Fiesta Dinnerware

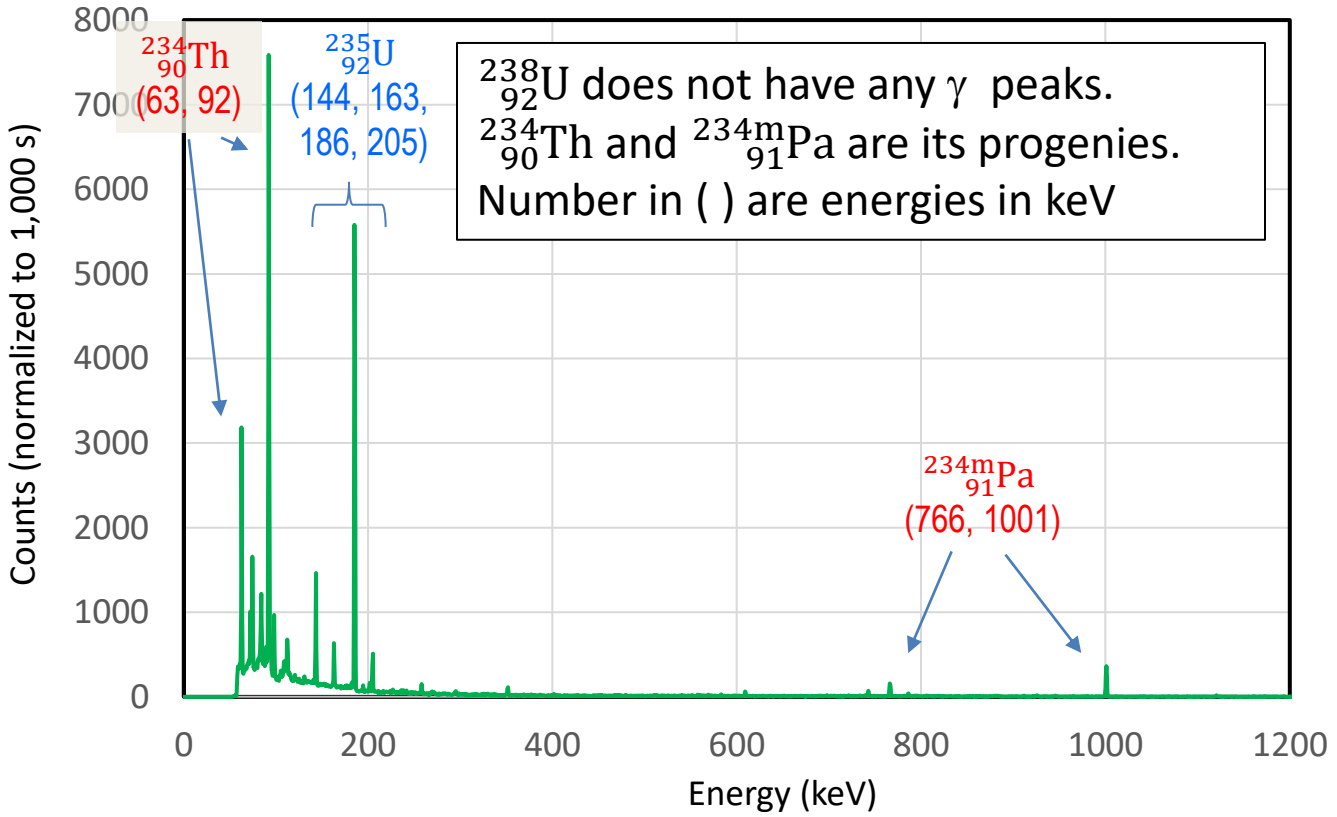
- Fiesta, often called, Fiestaware, is a line of ceramic glazed dinnerware manufactured and marketed by the Homer Laughlin China Company.
- Plates, cups, saucers were glazed with uranium compound to enhance appearance.
- First produced in 1936 – 1944 using uranium oxide in its glaze. (Many companies at that time also produce similar products.)

- During WW II, US government took control of all uranium in the country.
- From 1959 to 1972, used depleted uranium in the glaze.
  - Composition of natural uranium is: 0.7% U-235 & 99.3% U-238.
  - Depleted uranium is by-product of uranium enrichment with < 0.3% U-235 & > 99.7% U-238.
- Stopped using uranium after 1972. Old Fiestaware containing uranium are now collector items. Can be bought over many websites (including ebay – some sellers even advertised its radioactive properties!)

https://en.wikipedia.org/wiki/Fiesta_(dinnerware)

Fiesta Dinnerware

- Reading of up to 90 μSv/hr was obtained when GM tube is placed near the surface of plate!
- This reading decreases quite quickly over distance and when shielded with stack of papers, showing substantial alpha and beta radiation.
- Gamma radiation is of course also present. Peaks of $^{235}_{92}\mathrm{U}$, $^{234}_{90}\mathrm{Th}$ and $^{234\mathrm{m}}_{91}\mathrm{Pa}$ (protactinium) can be easily seen using a HPGe.



Is the Fiesta Dinnerware Safe?

- It was estimated that the plate contains up to 4.5 g of uranium with a glaze thickness of 0.2 mm.[1]
- External dosage: γ – about 6.5 μSv/h at 30 cm, β – 0.021 μSv/h at 30 cm
- Internal dosage – uranium leached into food. Estimated to be up to 0.4 mSv/yr if used for every meal (very conservative estimate on how long food stay on surface and acidity of food, etc.)
- Others have also assessed putting a set of these together, transporting and disposal. Under normal circumstances, do not constitute a high risk.
- US NRC: *Any person is exempt from the regulation and from the requirements for a license set … receives, possesses, uses, or transfers… Glazed ceramic tableware, provided that the glaze contains not more than 20 percent by weight source material (uranium).*

If interested, please read the details at US NRC Report on Systematic Assessment of Exemptions for Source and Byproduct Materials at https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1717/nureg-1717.pdf

1 http://www.orau.org/ptp/collection/consumer%20products/fiesta.htm

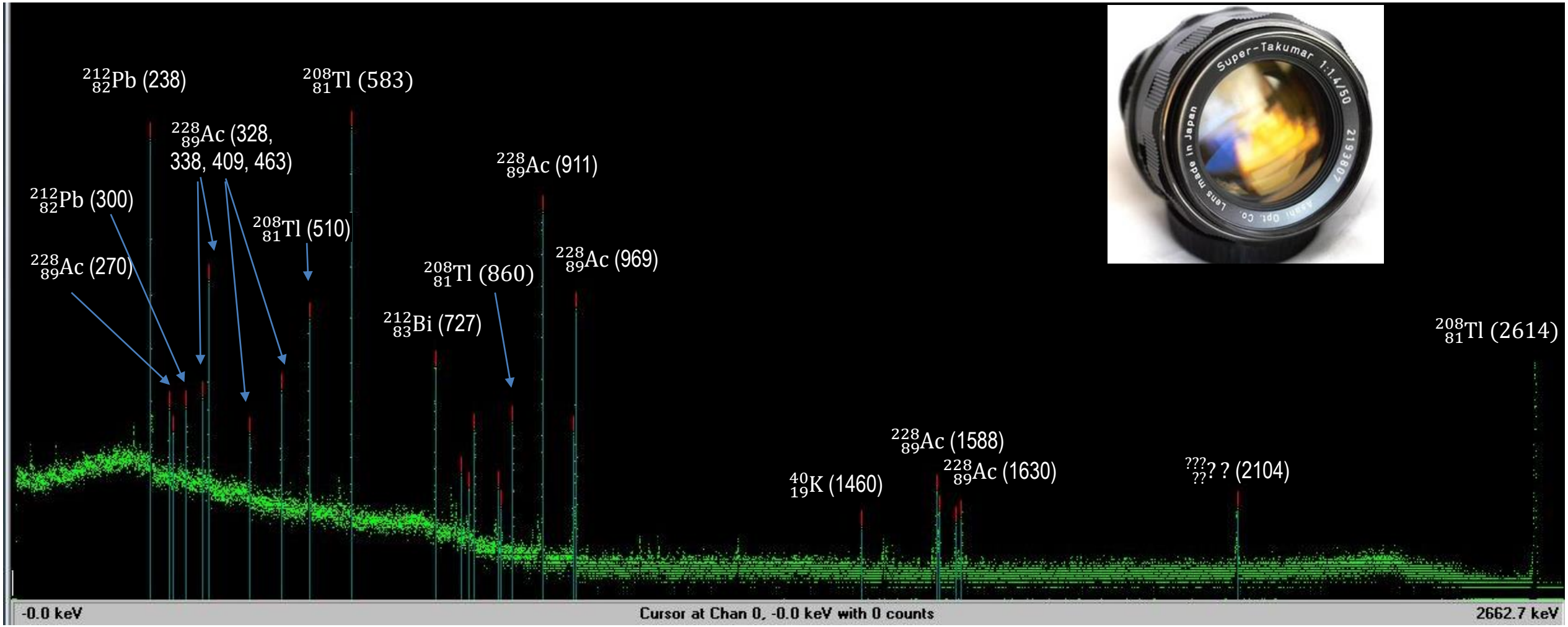
Some Old Camera Lenses

- A number of camera lenses (e.g., by Kodak, Canon, Pentax, Carl-Zeiss, etc.) made in 1940s to 1960s contain significant amount of thorium dioxide (up to 30%!). See list of these cameras in reference below.[1]
- Measurements of different lenses showed up to 1 – 100 μSv/h (on the lens surface and decreases substantially with distance so that at 1 m, it may be hard to discern it over the variation of background radiation.
- Not expected to be harmful to health unless such lens is used as eye-piece (placed very close to the eyes where the alpha and beta particles could produce more harm to the eye).
- Why did manufacturer use thorium dioxide?
  - high refractivity ⇒ can have utilize lenses of lower curvature and
  - low dispersion (different amount of ray bending for different colours) ⇒ minimize chromatic aberration

  So, the lens is less expensive to produce.

[1] http://camerapedia.wikia.com/wiki/Radioactive_lenses

Ex: Asahi Pentax Super-Takumar 50/1.4



Gamma spectrum using HPGe shows presence of Ac-228, Bi-212, Pb-212, Tl-208 (progenies of Th-232)

Ex: Asahi Pentax Super-Takumar 50/1.4

- Can find these lenses through ebay, etc. One tell-tale sign is the yellow-tint in glass due to the radiation on the glass.
- Overall, can still take good picture more than 60 years after manufactured! Perhaps prevents the growth of fungus that often appears on lenses and causes degradation of image??

Shot taken using this lens on Sony A7II camera at Sentosa SEA Aquarium

Gas Mantles

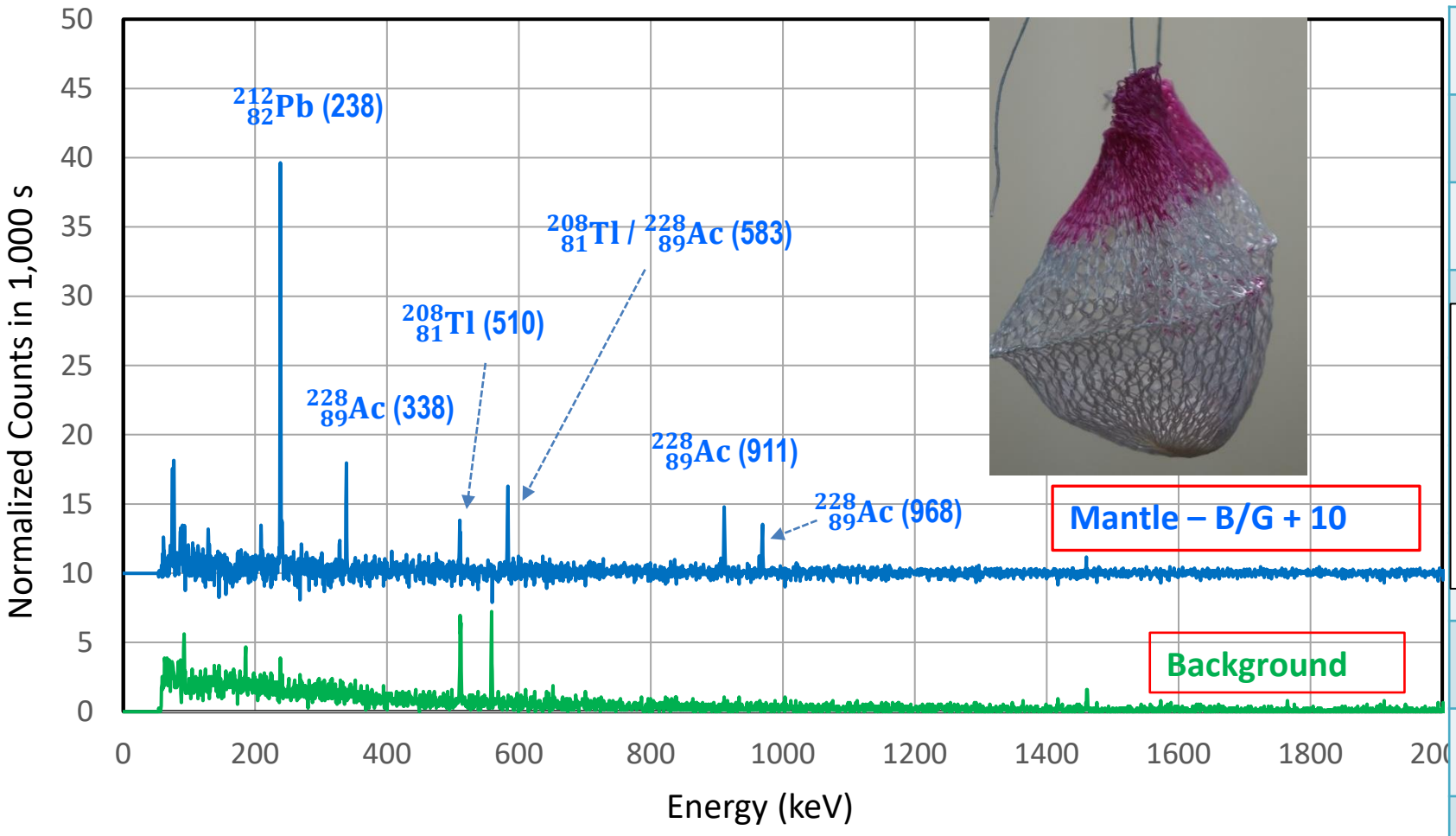
- Another household object that contains radioactivity is gas mantle.
- The gas mantle is a bag of cloth covered in metallic salts. These salts are oxidized in the presence of a flame, yielding a bright, long-lasting light.

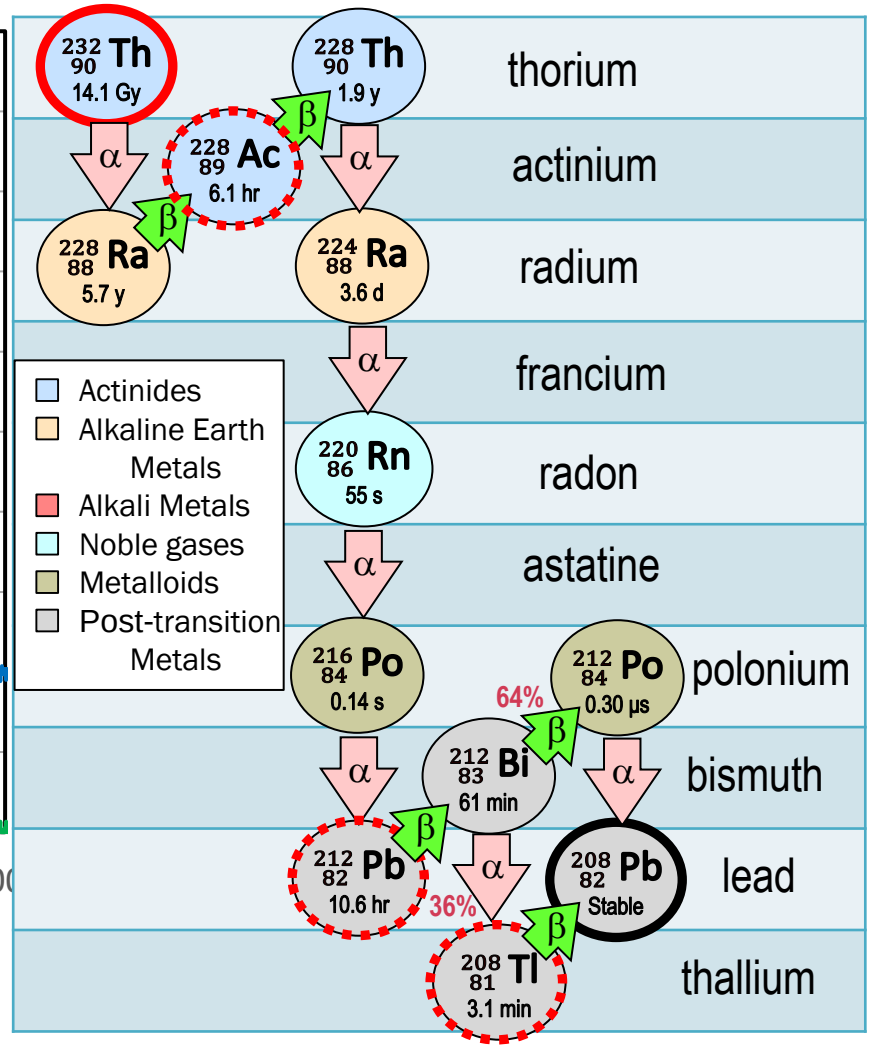
- Chemist Carl Auer von Welsbach, the father of modern gas mantles, experimenting with several mixtures of rare earth metals before settling on a mantle mixture containing 99% thorium dioxide in 1884.
- Some of newer mantles use yttrium instead but many mantles in retail lanterns still contain thorium, with 50 million mantles sold in the year 2000 containing the radioactive element.
- Dose is estimated to be ~ 0.05 μSv if one spends a couple of nights by Thorium gas lantern light.

http://io9.gizmodo.com/5889732/the-thorium-lantern-your-opportunity-for-retail-radiation-exposure

Gamma Spectrum of Gas Mantle

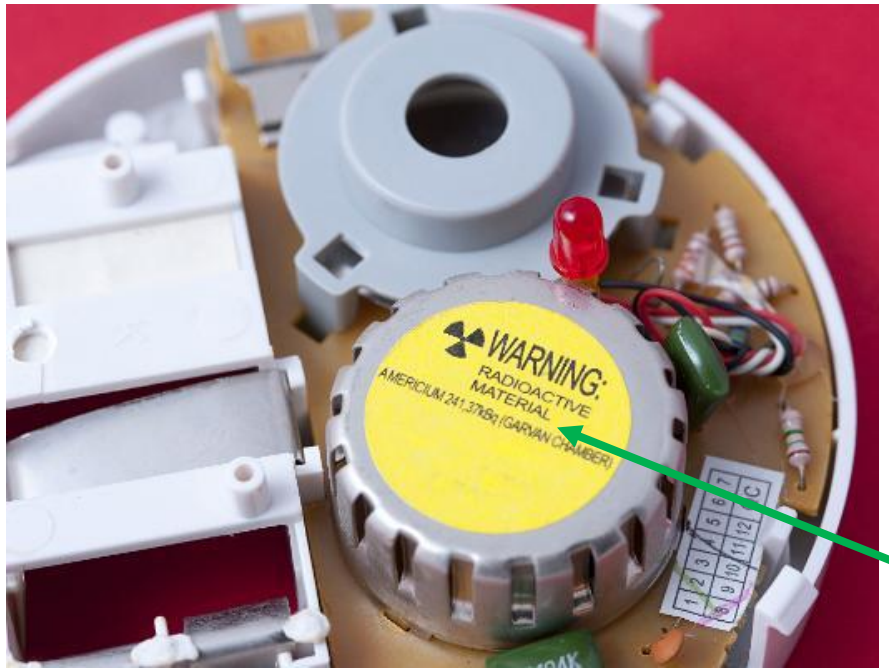
- This is the gamma spectrum of the gas mantle obtained taken with the HPGe.





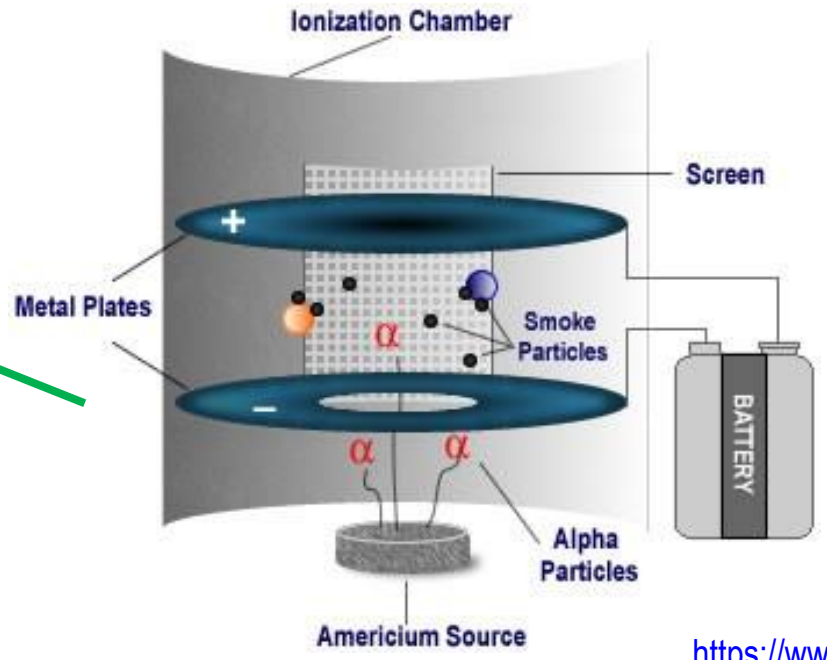
(Ionization Chamber) Smoke Detector

- This is probably the most common use of radioisotopes in homes and workplace and have saved many lives.
- Ionization Chamber – alpha particles from Am-241 source (usually 1 μCi) ionize the air molecules between the plates. Ions moved to the charged plates and there is current flow in circuit.



http://sciencestockphotos.com/free/electrical/slides/smoke_detector.html

- During fire, when smoke particles enter between the plates, they disrupt the current flow and alarm will sound.



- As Am-241 decays through alpha emission, so long as one do not open up the cover, it is generally very safe.

https://www3.epa.gov/radtown/americium-smoke-detectors.html

Safety of Smoke Detectors

- For a smoke detector using a 1 μCi americium source. the dose rate is estimated to be about 0.11 nSv/h (if uncovered), and 74 pSv/h if casing is intact at 1 meter from the source.[1]
- A resident who purchases, installs, and maintains two smoke detectors in the home, sleeps 8 h/day, and spends 4 h/day at other activities in the home could receive an annual dose of 0.01 μSv.
- The study also looked at doses from misuse. It found that a teacher who removed the source from a smoke detector could receive a dose of 0.09 μSv per year from storing it in the classroom. The teacher would get another 0.01 μSv from handling it for 10 hours each year for classroom demonstrations, and 6 mSv if he or she were to swallow it.
- It found that, in US, 10 million unwanted smoke detectors each year can be safely put in the trash.
- In a fire, the sources would release less than 0.1 percent of their radioactivity.

[1] https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1717/nureg-1717.pdf

Old Lightning Rods

- In the 1970s, many lightning rods were equipped with radioactive sources such as Ra-226 or Am-241 to enhance the efficiency of lightning rods. It was thought that the alpha particles emitted would create a charged field which will attract the lightning better.
- Many thousands of such rods were produced in many countries.

- Average activity for some sources collected in Brazil (16,000 of them) were measured to be in the range of 25 – 92 MBq (i.e., 0.67 – 2.5 mCi).
- Many thousands of such rods were installed in other countries including SE Asia.
- Found to be unjustified – no proven advantage over conventional lightning rods.
- Risk of exposure escalated due to damage by nature (rain, etc.).
- Disposal is also an issue – sources have level which can be dangerous.

http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/41/067/41067275.pdf

Radiation from TV?

- Older TV used cathode-ray tube technologies where electrons are accelerated through a very high voltage to hit the phosphorescent screen.
- Deceleration at the screen produces low-energy x-rays, majority of which are blocked by the thick glass.
- Nevertheless, some very low dose of radiation still occurs especially for TV addicts who views TV at a very close distance. Or computer users using old cathode-ray tube type of monitors at close range over long periods of time.
- Newer TV using LCD, plasma display and LED or OLED **no longer emit any <u>ionizing</u> radiation**.

http://sciencefacts.net/wp-content/uploads/2015/08/Cathode-Ray-Tube-TV.jpg

Announcements: Group Projects

1. Group Composition: Ideally 4
2. Members of group and title of topic to be submitted to me by 17 Feb (Friday of Week 6) (phycky@nus.edu.sg)
3. Your tutor will also serve as your advisor for the project
4. You may also consult me (during lecture hours or make an appointment with me)
5. **Video (25%)**
   - Duration of video: 4 minutes
   - Target audience: **General public**
   - Video to be uploaded 7 April (Friday of Week 12)
6. **Report (20%)**
   - 3,000 words in main text (excluding illustrations, appendices, etc.)
   - Target readers: Classmates in GET1024/GEC1036
   - Softcopy to be uploaded by 14 April (Friday of Week 13)

Announcements: Group Projects

Criteria for Assessment

- Understanding of scientific principles (10)
- Logical discussion and conclusion (10)
- Appropriate choice of examples (5)
- Ability to arouse interest of audience (5)
- Combination of scientific and social aspects (5)
- Appropriate report / video format (5)

Bonus points may also be given for creativity or for reports / videos beyond expectation.

Announcements: Group Projects

Possible Topics

- Background radiation level in Singapore
- Radioactive objects around us
- Applications of radiation in the past
- Least known applications of radiation
- Applications of radiation to combat climate change
- Is nuclear power the solution to climate change?
- Can / should Singapore go nuclear – why or why not?
- If Singapore needs nuclear in the energy mix, what reactors can she use?
- The economics of nuclear power
- Food irradiation – benefits vs risks
- Public opinions towards radiation

Any other topics (on radiation or its application) that you feel you would like to work on – but please consult me personally or via email.