Lecture 44
S-90, Y-90 in the environment

NO READING!

Today
a. Sr-90 and Y-90: uses and sources.
b. Global fallout and issues.

Facts about Sr (and Sr-90)

Some content modified from:
http://pubs.acs.org/cen/80th/print/strontium.html

- The metallic element strontium (Sr) was first identified in 1790. It has four stable isotopes.
- One common use of stable elemental Sr is in flares and fireworks, as a crimson colorant
- Sr is an alkaline earth element (i.e., the same chemical family as calcium
- Some people know of Sr because of it's dangerous radioactive form, Sr-90.
- There are also a number of other radioactive isotopes of strontium, but only Sr-90 has a long enough half-life to present a persistent hazard (29.1 years)

Strontium imparts a crimson color to fireworks.

Facts about Sr-90

Modified from:
http://pubs.acs.org/cen/80th/print/strontium.html

http://www.radiologyinfo.org/

- Sr-90 is created during nuclear explosions or in nuclear reactors by fission of heavy nuclei, such as uranium-235 and plutonium-239.
- Strong chemical similarity between Sr and Ca is the principal reason why radioactive Sr-90 is dangerous.
- When it is ingested or inhaled, radioactive Sr is processed by the body in the same way as calcium and winds up in bones. This *internal radiation source* creates a risk of cancer, especially bone cancer and leukemia.

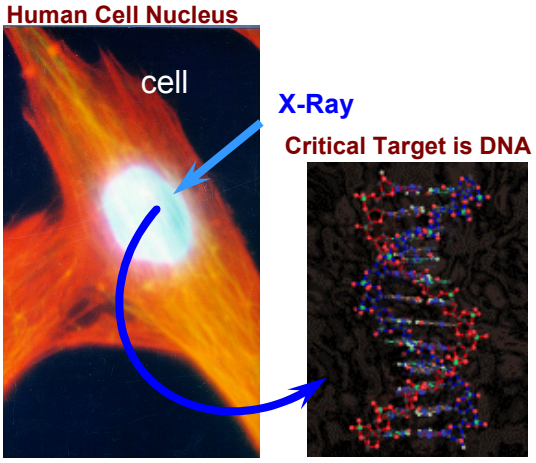
Facts about Sr-90

Modified from:
http://pubs.acs.org/cen/80th/print/strontium.html

- Sr-90 emits ionizing $\beta-$ radiation at a specific activity of about 138 curies per g.
- Sr-90 β-average energy is 0.196 MeV, maximum is 0.546 MeV.
- Sr-90 decays into short-lived decay product Y-90 (Half life= 64.1 hours), which is also a $\beta-$ emitter.
- Y-90 β-average energy is 0.93 MeV (2.28 Mev max.)
- Sr-90 and Y-90 two are normally in secular equilibrium (decaying at the same rate), thus doubling the specific activity of the material that contains these isotopes.

Facts about Sr-90

- Sr-90 can cause biological from outside the body (as an *external radiation source*) from the formation of X-rays called brehmstrahlung (German for braking).
- These X-rays are produced by the slowing down of the β– as they interact with tissue and water in your skin.
- This radiation penetrates the body and ionizes molecules, increasing cancer risk.



Facts about Sr-90

Modified from:
http://pubs.acs.org/cen/80th/print/strontium.html

- Sr-90 pollution first attracted international attention during the atmospheric nuclear weapons tests in the 1950s.
- Sr-90 and Y-90 became an important component of the global radioactive fallout, like Cs-137 (discussed last week).
- A U.S. hydrogen bomb test at Bikini in 1954 caused a serious fallout incident on Rongelap Atoll and on a Japanese fishing boat, bringing worldwide attention to the issues related to nuclear weapons testing.

Sr-90 Toxicology

The principal ecological pathway to humans is:

grass→ cow→ milk→ human food chain.

There are two main exposure pathways

A. Internal (ingestion, inhalation)
B. External (dermal contact)

Today, ingestion and inhalation are the most likely ones for the average person.

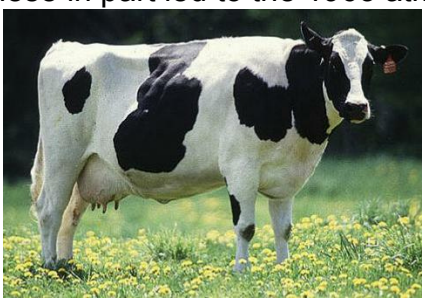
History of Monitoring Sr-90/Y-90 in humans

Gould et al., 2000, "Strontium-90 in Newborns and Childhood Disease" Archives of Environmental Health

- Early monitoring of radioactivity levels in humans was began with atmospheric nuclear weapons testing in January 1951.
- Subsequent studies focused on the radionuclide Sr-90, which concentrates in bone, damaging stem cells of the bone marrow critical to reproduction of cells that mediate immune function.
- Y-90 concentrates in the soft glandular tissues, including the pituitary gland, which controls hormonal function.

History of Monitoring Sr-90/Y-90 in humans

- By July 1953, Sr-90 had been detected in animal bones and milk products.
- Sr-90 contamination of milk became an important issue.
- Tests of bones and baby teeth from around the world (including a landmark study of 60,000 baby teeth in the St. Louis area published in 1961) showed Sr-90 levels rose steadily during atmospheric nuclear testing.
- These in part led to the 1963 atmospheric test ban treaty.



History of Monitoring Sr-90/Y-90 in humans

- Peak Sr-90 levels were reached in 1964, shortly after the passage of the Limited Test Ban Treaty, and levels dropped rapidly thereafter.
- absorption of elevated levels of Sr-90 and other radionuclides in bomb test fallout was subsequently, linked with increased disease risk (e.g., U.S. childhood leukemia rates were correlated with levels of Sr-90 in milk from bomb test fallout.
- Cancer incidence in children under the age of 5 y in Connecticut quickly increased 40% between 1948-1950 and 1962-1964.
- The cancer rate quickly fell 30% *after* atmospheric bomb testing ceased (i.e., by 1967-1969).

History of Monitoring Sr-90/Y-90 in humans

- Sr-90 levels were dropping so various baby teeth and vertebrae studies were terminated by U.S. governmental agencies between 1970 and 1982.
- However, declines in Sr-90 activities in the urban northeast United States had slowed after 1975, remaining at 1957 levels.
- Nuclear power reactors have been implicated as a new source of Sr-90 radioactivity to the American environment was.

- Radioactive emissions from reactors are linked to childhood leukemia rates in the United States and abroad. A 2000 study showed that infant mortality and cancer in local children younger than 5 declined after closure of 5 nuclear power plants.

Sr-90 sources to the environment

- Fission product of U-235 and Pu-239.
- Atmospheric Fallout from weapons testing (probably the most dangerous component, but fairly well diminished now, see lectures last week).
- Waste materials (liquid waste stream) from nuclear power plants. It is not released to the environment during normal reactor operations, nor is it as likely as Cs-137 to be released as a part of a reactor accident because Sr is much less volatile
- Medical Waste.

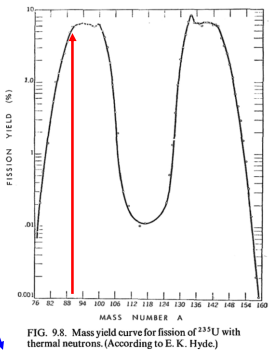
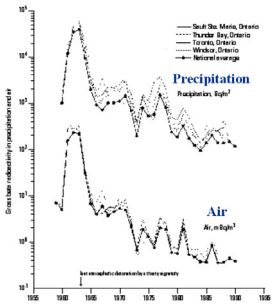


FIG. 9.8. Mass yield curve for fission of ^{235}U with thermal neutrons. (According to E. K. Hyde.)



Sr-90 uses

- Used in medical imaging devices
- Sealed Sr-90 (and other isotopes) sources are used to treat cancer.
- Sr-90 also has some uses in luminous signs, nuclear batteries and industrial gauging.
- RTGs radioisotope thermoelectric generators, where the energy of β- particles is captured as heat and converted to electricity with thermocouples.

  Each RTG typically contains tens of thousands of curies (several hundred grams) of Sr-90.

Sr-90 spills

- RTGs have been used to power remote seismic stations in Alaska and, far more commonly, in remote areas of the former Soviet Union.
- The system for keeping track of Sr-90 power sources fell into disarray after the disintegration of the Soviet Union.
- RTGs with Sr-90 are a source of danger to the local population (e.g., hunters in the Republic of Georgia have been accidentally irradiated).
- There is also the risk that they could be used by terrorists to make radiological weapons. A little over 10 μg of Sr-90, if inhaled in insoluble form, would give a sufficient dose to cause cancer with high probability.
- RTGs using plutonium-238 (half-life = 87 years) are now preferred because they are smaller and need less shielding.

Sr-90 spills

- Sr-90 pollutes soil and water at some U fuel reprocessing plants, such as:
  - the Savannah River Site in South Carolina
  - the Hanford Site in Washington state
  - the Mayak plant in Russia
- An explosion of a high-level waste tank at Mayak in 1957 released 20 million curies of radioactive fission products into the environment.
  - About 5% of this was Sr-90 and Y-90
  - 10% of this fallout of this was deposited over an area of 15,000 to 23,000 km^2, necessitating the evacuation of more than 30 towns and villages.

A Recent Occurrence of elevated Sr-90/Y-90 in humans

Gould et al., 2000, "Strontium-90 in Newborns and Childhood Disease" Archives of Environmental Health

- In 1998, the Radiation and Public Health Project (RPHP) began studying Sr-90 concentrations in baby teeth in Suffolk County (Long Island) New York to investigate the decline in children's health in the area.
- Brookhaven National Laboratories in in Suffolk County. It has operated two or three research reactors since 1950. The county also lies ~70 mi from the Indian Point, New York and Oyster Creek, New Jersey reactors, which can send particulate plumes to the county.
- 1,700 teeth were received by 2000, of which 515 were analyzed for Sr-90 content

A Recent Occurrence of elevated Sr-90/Y-90 in humans

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Results and conclusion

Birth period (teeth)	Diagnosis period (cancer)	High pCi Sr-90/g Ca	Ave pCi Sr-90/g Ca
1979-1981	1982-1984	3.45	1.11 (11) †
1982-1984	1985-1987	2.6	1.26 (23) †
1985-1987	1988-1990	7.26	1.5 (70) †
1988-1990	1991-1993	7.86	1.45 (110) †

Birth Period (teeth)	Diagnosis period (cancer)	Cancer incidence(*) Ages 0-4 y
1979-1981	1982-1984	17.4 (46) ‡
1982-1984	1985-1987	20.17 (55) ‡
1985-1987	1988-1990	25.52 (73) ‡
1988-1990	1991-1993	19.29 (58) ‡

Notes:
pCi Sr-90/g Ca = picocuries strontium-90 per gram calcium.
(*) cases per 100,000
† Numbers of teeth analyzed in parentheses (of a total of 515).
‡ Numbers of cancer cases in parentheses.

"The increase in *in vivo Sr-90,* occurring at a time of rising childhood cancer rates, repeats patterns found in the era of atmospheric nuclear weapons testing. Current concentrations of Sr-90 in Suffolk County and other American children correspond roughly to concentrations found in St. Louis children born in 1956, 5 y after atmospheric nuclear testing in Nevada commenced" ".. and far exceed levels expected after large-scale American and Soviet atmospheric tests [stopped]". Thus, another source of fission products must be contributing to the current levels; most likely, these are emissions from nuclear reactors."

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