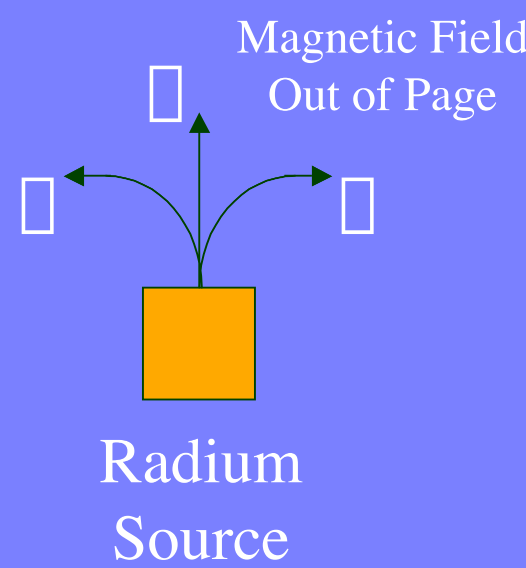
Lecture 7: Radiation and Health



Curie, Becquerel, Jolliot ...

- Types of ionizing radiation
  - Alpha particles 24He++ “nuclei”
  - Beta particles negative electrons
  - Gamma particles: photons
    - X-ray energies 10’s-100’s keV
    - □-ray energies: 500 keV and higher
  - Neutrons (01n “nuclei”) (disovered by Chadwick - 1932)

Alpha Particles

Produced in decay of **HEAVY** nuclei: ^{226}Ra -> ^{222}Rn + ^{4}He)

Conservation of CHARGE (Z)	88	=	86	+	2
Conservation of Nucleons (A)	226	=	222	+	4

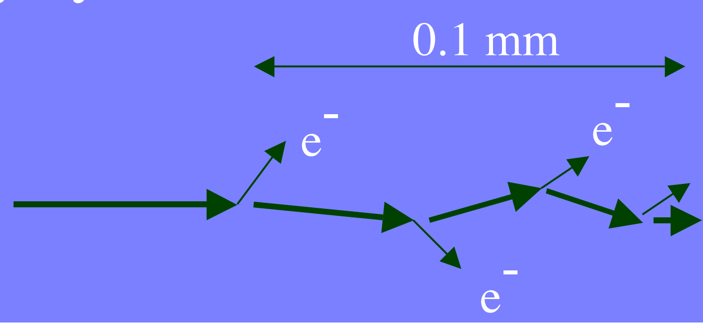
Conservation of ENERGY $m(^{226}Ra)c^2 = m(^{222}Rn)c^2 + m(^{4}He)c^2 +$ □

Nuclear Energy (MeV's)

Other alpha decays: ^{238}U -> ^{234}Th + □ ($t_{1/2} = 4.5 \times 10^{9}$ y)

^{232}Th -> ^{228}Ra + □ ($t_{1/2} = 1.4 \times 10^{10}$ y)

Alphas loose energy by IONIZATION



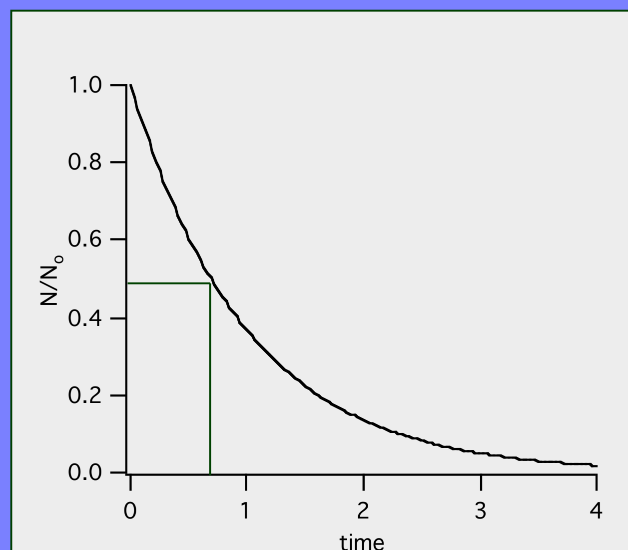
Short Range

High Specific Ionization/

Energy Deposited

Half life

Radioactive decay: $\frac{dN}{dt} = -N/\tau$ $\quad N = N_0 e^{-t/\tau}$ (t is time)



$t_{1/2} = \tau \ln 2 = 0.69t$

Beta Decays

Electrons and Positrons are Beta-particles

$m = 9.1 \times 10^{-31}$ kg; $mc^2 = 0.511$ MeV

$q = \pm 1.6 \times 10^{-19}$ Coulombs

Neutron Rich Isotopes □$^-$ decay: $^{234}Th \rightarrow {}^{234}Pa + e^- +$ □ $(t_{1/2} = 24.1$ d)

Conservation of CHARGE (Z) 90 = 91 - 1

Conservation of Nucleons (A) 234 = 234 +0

Conservation of ENERGY $m(^{234}Th)c^2 = m(^{234}Pa)c^2 + m(^{e})c^2 +$ □

Betas are PENETRATING (similar to gamma rays)

Longer Range than Alpha Particles

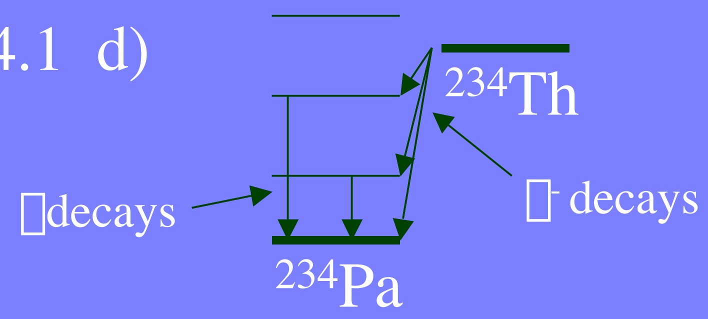
Lower Specific Energy Loss

Gamma Rays (Photons)

Produced by Brehmstralung (of high energy electrons)

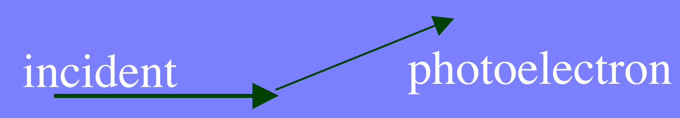
Produced in NUCLEAR TRANSITIONS

$^{234}Th \rightarrow {}^{234}Pa^{*} + e^{-} + \bar{\nu}$ ($t_{1/2} = 24.1$ d)

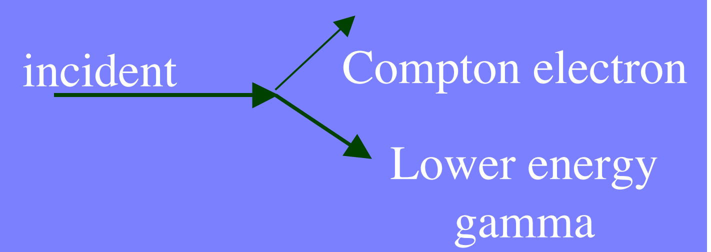


Photon interactions:

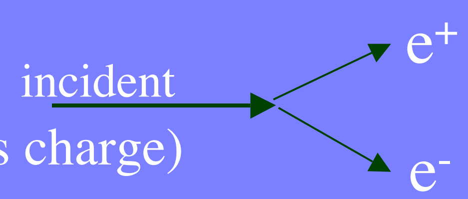
Photoelectric effect (ionizing)



Compton Scattering (ionizing)



Pair Production (for $E_{\gamma} > 1.022$ MeV)



(conserves charge)

Penetration and Shielding

Ionizing radiation interacts with materials

Alphas loose energy by ionization

Range (to KE=0) ~ m/Z << 1 mm

Betas loose energy by ionization

range ~ 1/Z

Gammas (photons) transfer energy to electrons

Attenuation ($e^{-\Box\Box t}$) depends on Z, $E_{\Box}$

Harmful Effects of Ionizing Radiation

- Ionizing Radiation: dislocates electrons/atoms
  - H_2O + radiation -> $H_2O^+ + e^-$: OH, H^+, H, OH^-, H_2O_2
    - Early cell death
    - Inhibited cell division
    - Genetic modification of chromosomes
- Units of exposure:
  - Becquerel/ Curie (activity) 1 Bq=1/s 1 Cu = 3.7×10^{11} Bq
  - Gray/Rad (absorbed dose) 1 Gr= 1 J/kg 1 rad = 0.01 Gr
  - SV/Rem(includes biological effectiveness - RBE)
  - RBE's
    - 1 for x-rays
    - 5 slow neutrons
    - 20 for alpha particles, fast neutrons, protons

Dose Calculations

Alphas: 1 µCurie of 5 MeV alpha emitter (ingested)

(biological half-life = $t_{1/2}$ = 1 day)

5 MeV = $5*10^{6}*1.6\times10^{-19}$ J = 8×10^{-13} J

1 µCu = 3.7×10^{4} Gr = 1.33×10^{7}/hour = 3.2×10^{8}/day

Whole Body (70 kg) Dose = $(8\times10^{-13}\text{ J})(3.2\times10^{8}\text{/day})(1.44\ t_{1/2})/(70\text{ kg})$

= 5.3 µGr = 0.5 mRad

RBE for alphas = 20 so EFFECTIVE DOSE = 10 mRem

DANGER: energy can be deposited in more **localized** region

Allowed Dose and General Exposure

Allowed Dose: 5 mSv = 500 mRem per Year (General Public)

Natural Radioactivity	Total	299 mRem/Y
Local Gamma Rocks etc.		29
^{14}C ($t_{1/2}$ = 5739 y)		1
Airborne radon		200
^{40}K (0.117%/$t_{1/2}$ = 1.3×10^9 y)		20 (bannanas, etc.)
U, Th in body		19
Cosmic Rays		30
doubles each 6000 ft: @ 36,000 feet 64x about 1mR/kmile		
Manmade Radioactivity		
Diagnostic X-rays		40
Radioacitive waste		0.2
Fallout (atmospheric testing)		0.1

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People & Discoveries
History
What Is Radiation?
Types of Radiation
Symbols
Careers
Links

Fun Stuff -Take a Quiz

Calculate Your Dose
Puzzles: Word Search
Cross Word

Calculate Your Radiation Dose

Directions

1. Enter values or select entries where options are provided. (Some entries for the annual dose calculator are already filled in.)
2. Click the "calculate dose" button.

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Source	Your Average Annual Dose (mrem)
Cosmic radiation at sea level (from outer space)	26
What is the elevation (in feet) of your town?	up to 1000 (2 mrem)
Terrestrial (from the ground):	
What region of the US do you live in?	Elsewhere in the US (46 mrem)
Internal radiation (in your body):	
From food and water, (e.g., potassium)	40
From air, (radon)	200
Do you wear a plutonium powered pacemaker?	No (0 mrem)
Do you have porcelain crowns or false teeth?	Yes (.07 mrem)
Travel Related Sources:	
Add 1 for each 1000 miles traveled by jet this year:	25
Are X-ray luggage inspection machines used at your airport?	Yes (.002 mrem)
Do you use gas lantern mantles when camping?	No (0 mrem)
Miscellaneous Sources:	
Weapons test fallout	1
House construction: Do you live in a stone, brick, or concrete building?	No (0 mrem)
Do you wear a luminous wristwatch (LCD)?	No (0 mrem)
Do you watch TV?	No (0 mrem)
Do you use a computer terminal?	Yes (.1 mrem)
Do you have a smoke detector in your home?	Yes (.008 mrem)
How many medical x-rays do you receive per year? (40 mrem each)	1

medical procedures do you receive per year? (14 mrem each) | 0

Do you live within 50 miles of a nuclear power plant? | Yes (.009 mrem)

Do you live within 50 miles of a coal fired power plant? | Yes (.03 mrem)

TOTAL YEARLY DOSE (in mrem)
380.219 | calculate dose

Notes

- The amount of radiation exposure is usually expressed in a unit called millirem (mrem). In the United States, the average person is exposed to an effective dose equivalent of approximately 360 mrem (whole-body exposure) per year from all sources (NCRP Report No. 93).]
- The dose calculator is based on the American Nuclear Society's brochure, "Personal Radiation Dose Chart". The primary sources of information we relied on are the National Council on Radiation Protection and Measurements Reports #92-#95, and #100. Please remember that the values used in the calculator are general averages and do not provide precise individual dose calculations.

  Info National Council on Radiation Protection and Measurements Exit EPA

- Special thanks to UT-ANS group for providing the CGI script that was used to construct this yearly dose calculator web page.

Info Radiation: Risks and Realities
information on radiation, radiation uses and risks

Understanding Radiation

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Cancer Risk

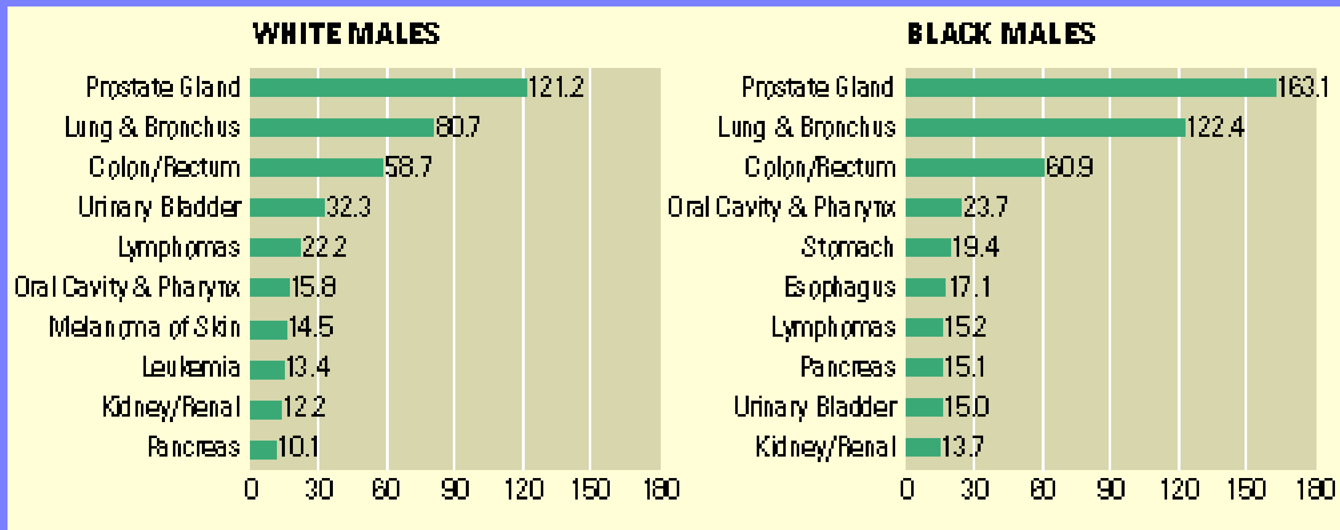
Cases per 1000 Sv (10^5 Rem)

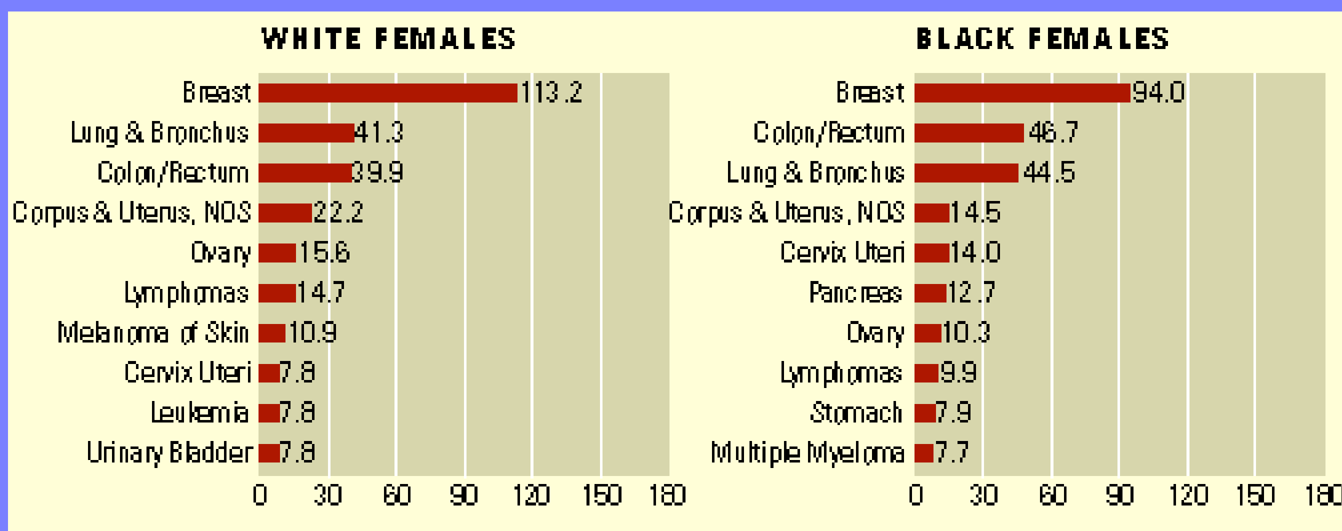
	Male	Female
Leukemia	2	2
Breast	-	5
Lung	2	2
Thyroid	0.5	0.5
Bone Sarcoma	0.5	0.5
Other	5	5
Total	10	15

Assumes the Linear model:
1000 people@ 1 SV ~ 1000000 people @ 0.001 Sv

http://seer.cancer.gov

Total Cancer Rates per 100,000





Source: NIH (http://rex.nci.nih.gov/NCI_Pub_Interface/raterisk/rates12.html)

Typical Dose

• Chest Xray	20 mR
• Brain Xray	250 mR
• Abdomen	550 mR
• Dental	10 mR
• Mammography	50 mR
• CT slice	1000 mR
• Liver tumor	6000 R !

Radiation Safety

- Time: $N=N_0\, e^{-t/\Box}$
- Distance: $I \sim 1/r^2$
- Shielding: $I=I_0\, e^{-\Box/\Box}$
- Monitoring (radiation detection)