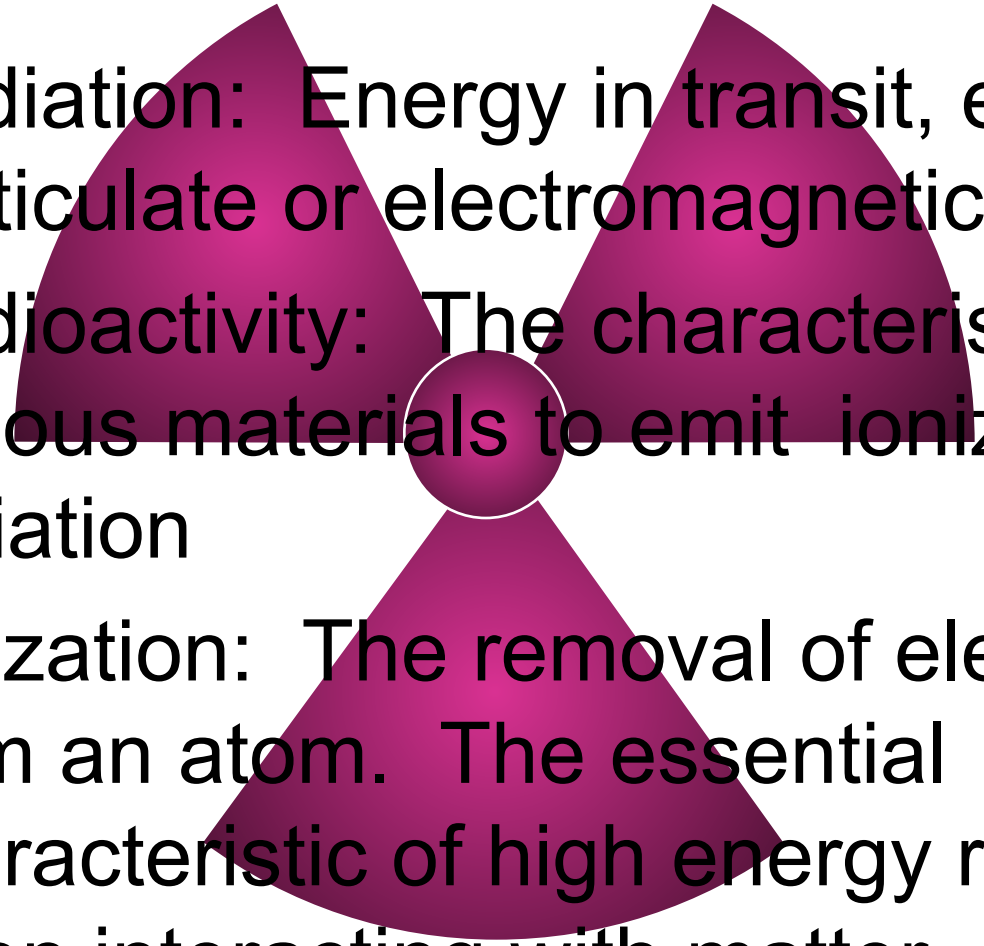
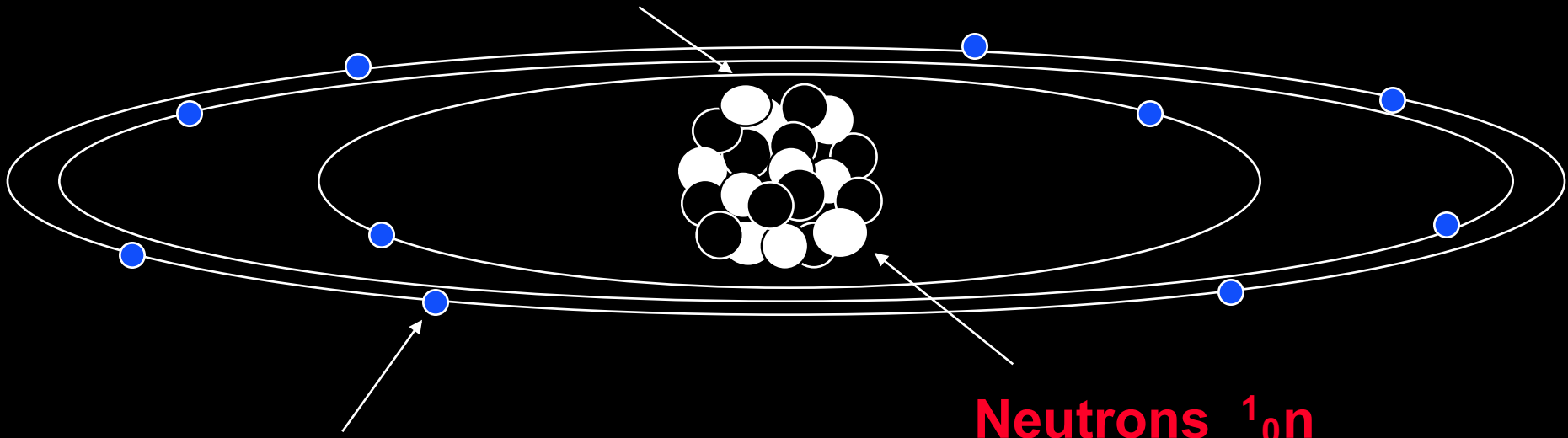
Radiation and Radioactivity



- Radiation: Energy in transit, either particulate or electromagnetic in nature
- Radioactivity: The characteristic of various materials to emit ionizing radiation
- Ionization: The removal of electrons from an atom. The essential characteristic of high energy radiations when interacting with matter.

The Atom

Protons $^{1}_{1}p$
(1.007276 amu)

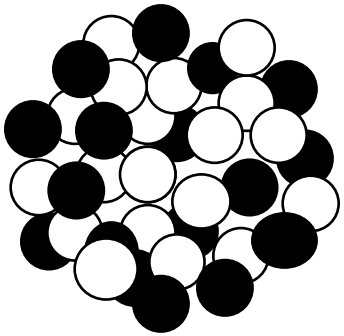


Neutrons $^{1}_{0}n$
(1.008665 amu)

Electrons
(0.0005486 amu)

Neon-20 $^{20}_{10}Ne$
(19.992434 amu)

Alpha Decay



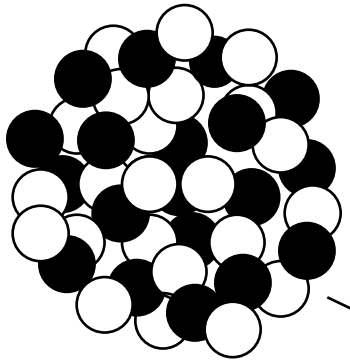
Daughter Nucleus

Np-237

Th-234

Ra-228

Rn-222



Parent Nucleus

Am-241

U-238

Th-232

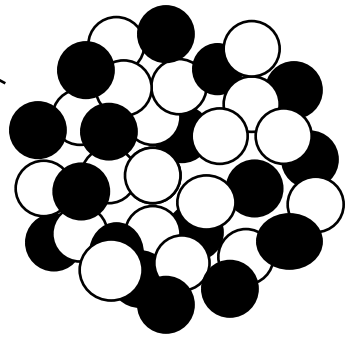
Ra-226

$^{4}_{2}\alpha^{++}$

Alpha Particle (Helium Nucleus) (4.00147 amu)

Beta (Negatron) Decay

Daughter Nucleus
Osmium-187
Calcium-40



$^{0}_{0}\nu$

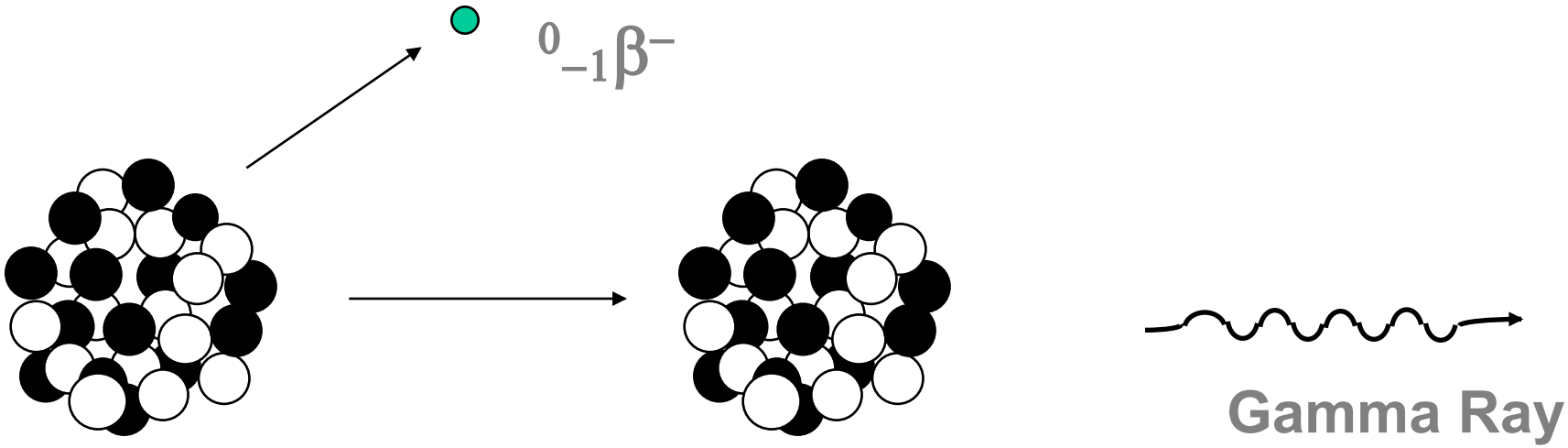
Antineutrino

Parent Nucleus
Rhenium-187
Potassium-40

$^{0}_{-1}\beta^{-}$

Beta Particle (electron)

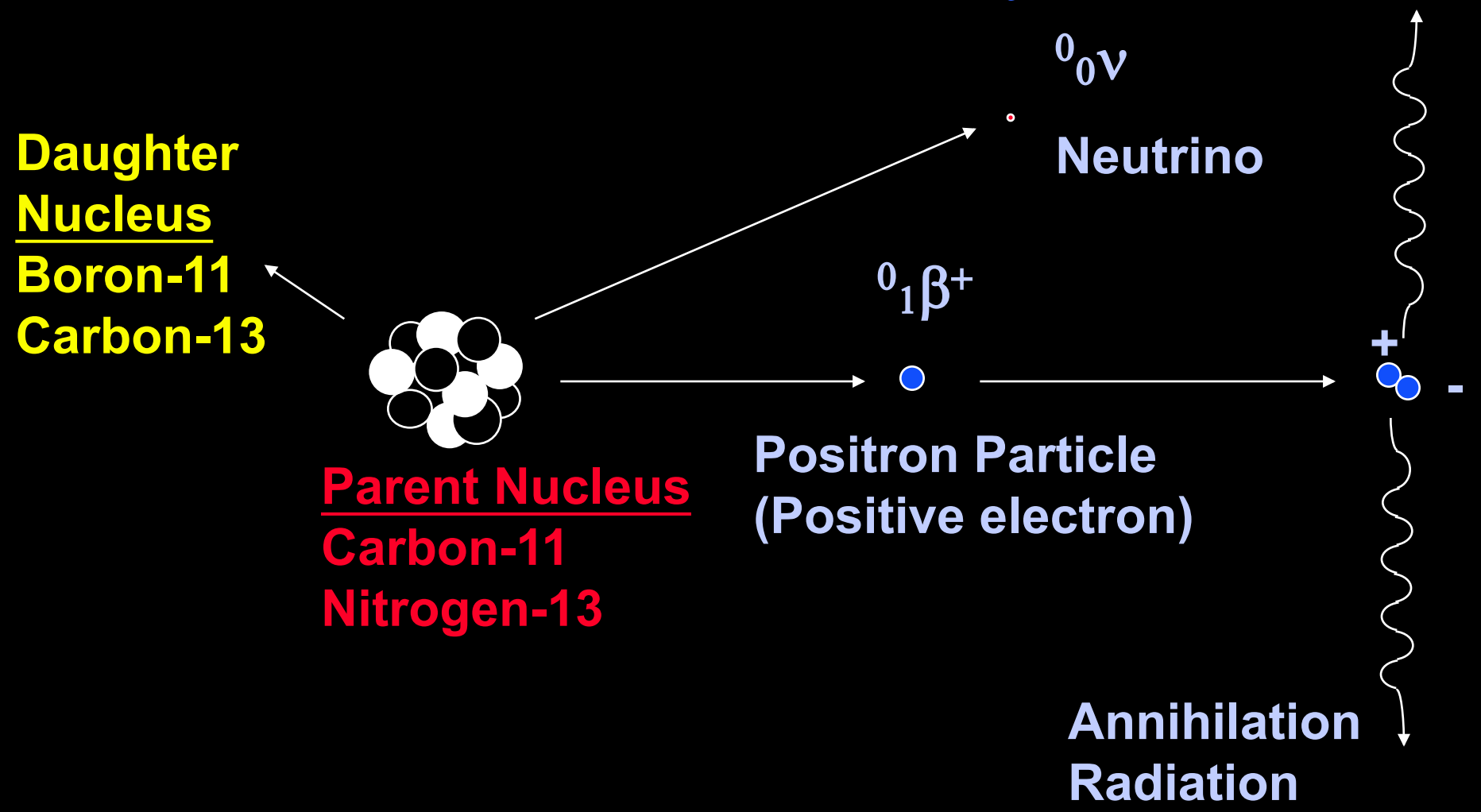
Gamma-Ray Emission



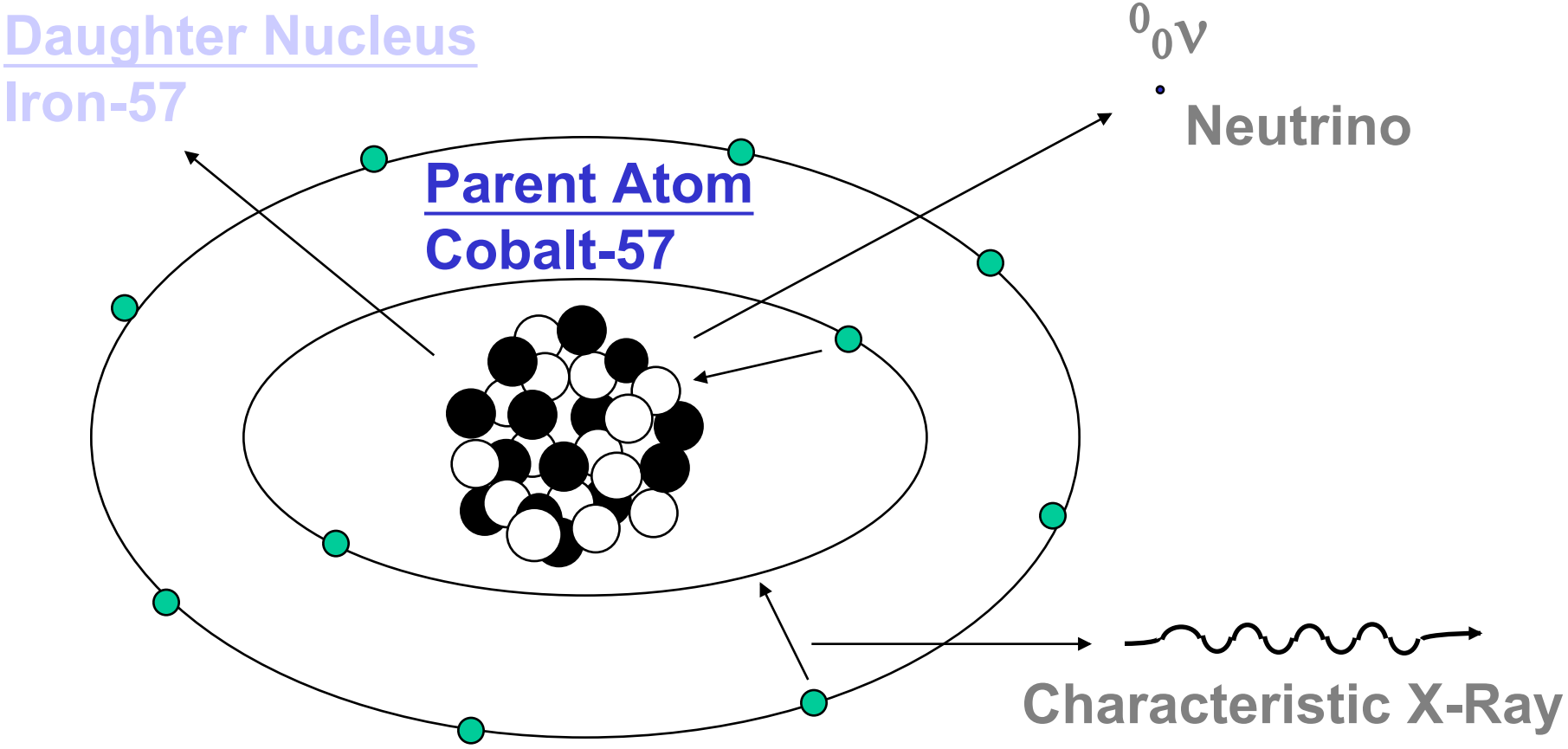
Parent Nucleus
Cesium-137
Molybdenum-99

Daughter Nucleus
Barium-137m
Technetium-99m

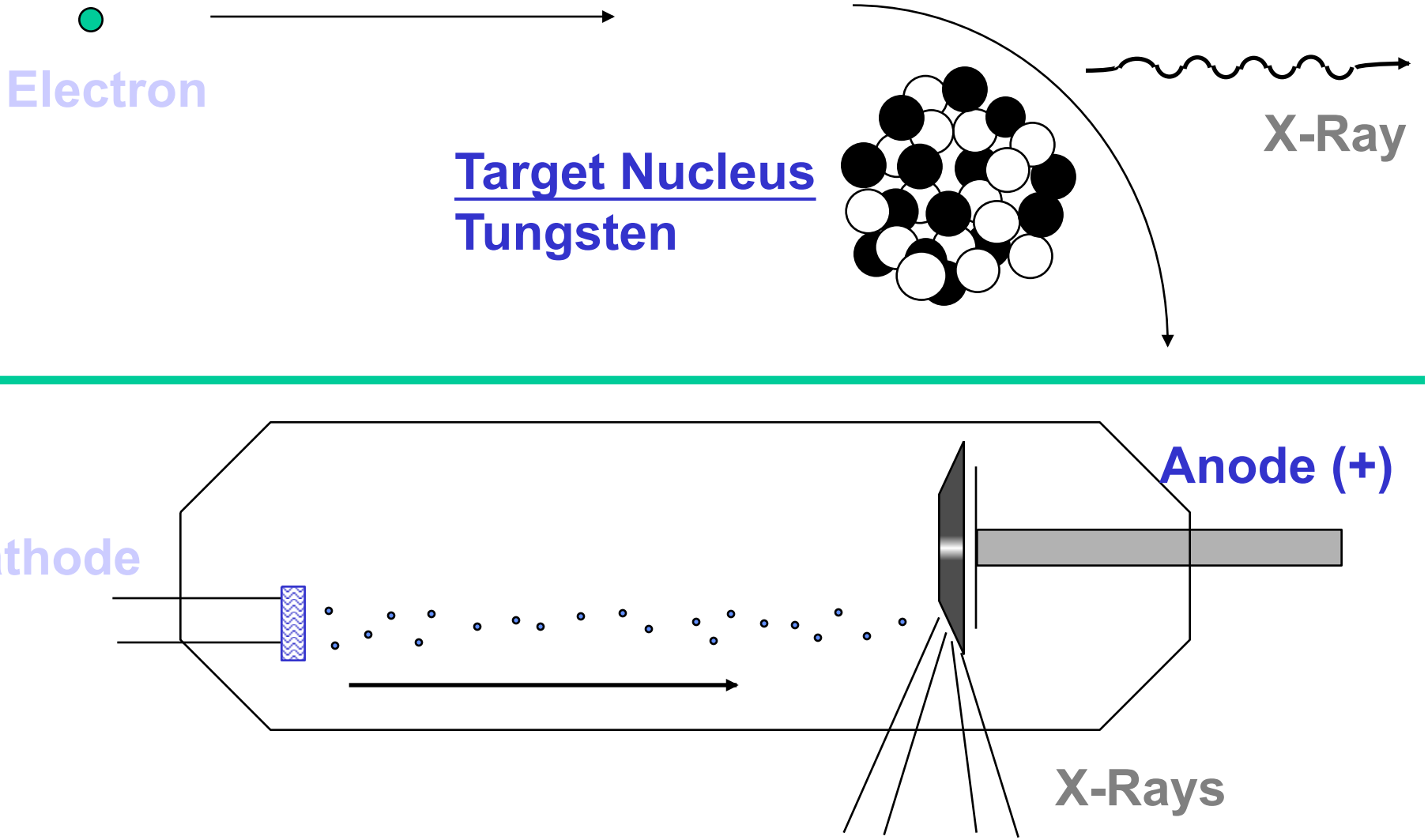
Positron Decay



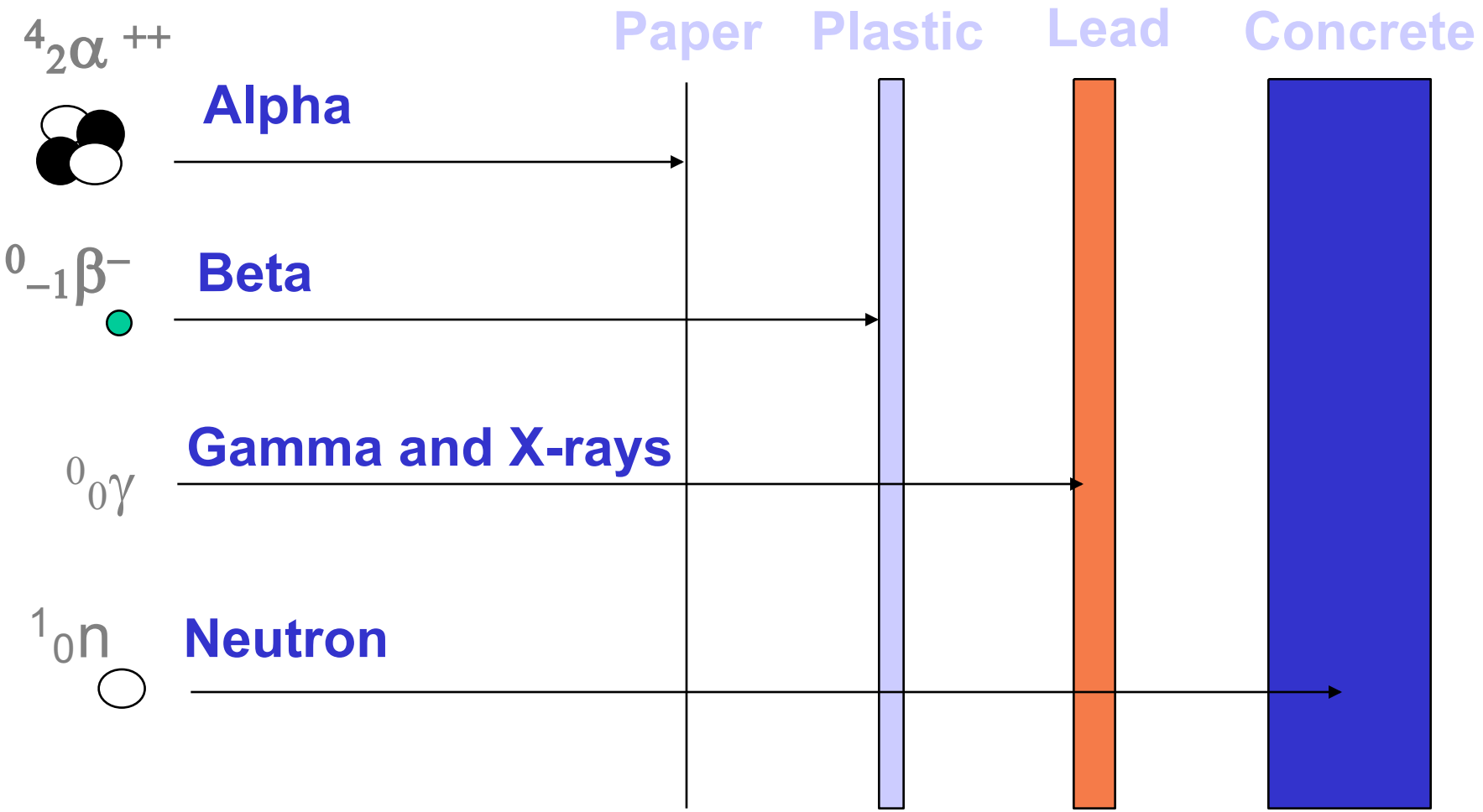
Electron Capture and Characteristic X-Rays



X-Ray Production (Bremsstrahlung)



Types of Radiation

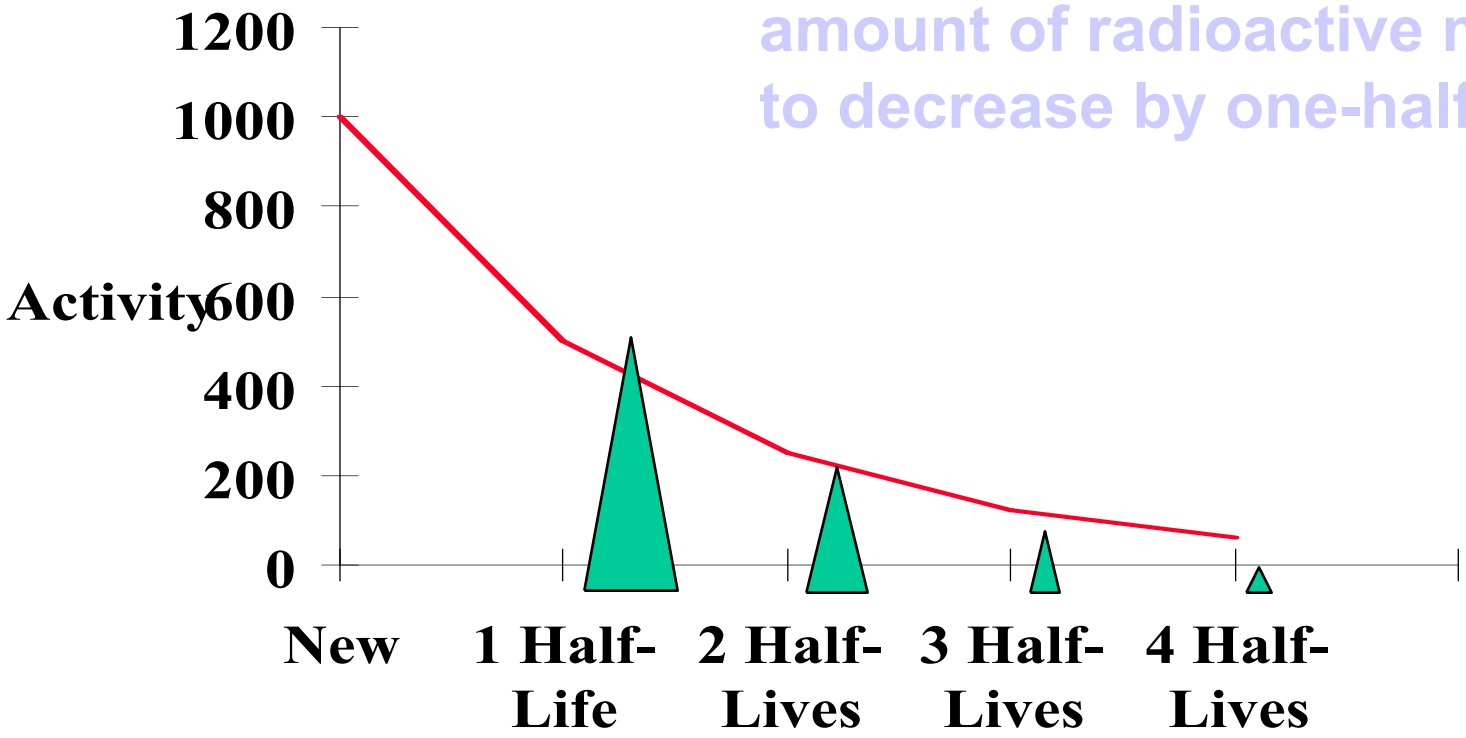


Measures of Radioactivity

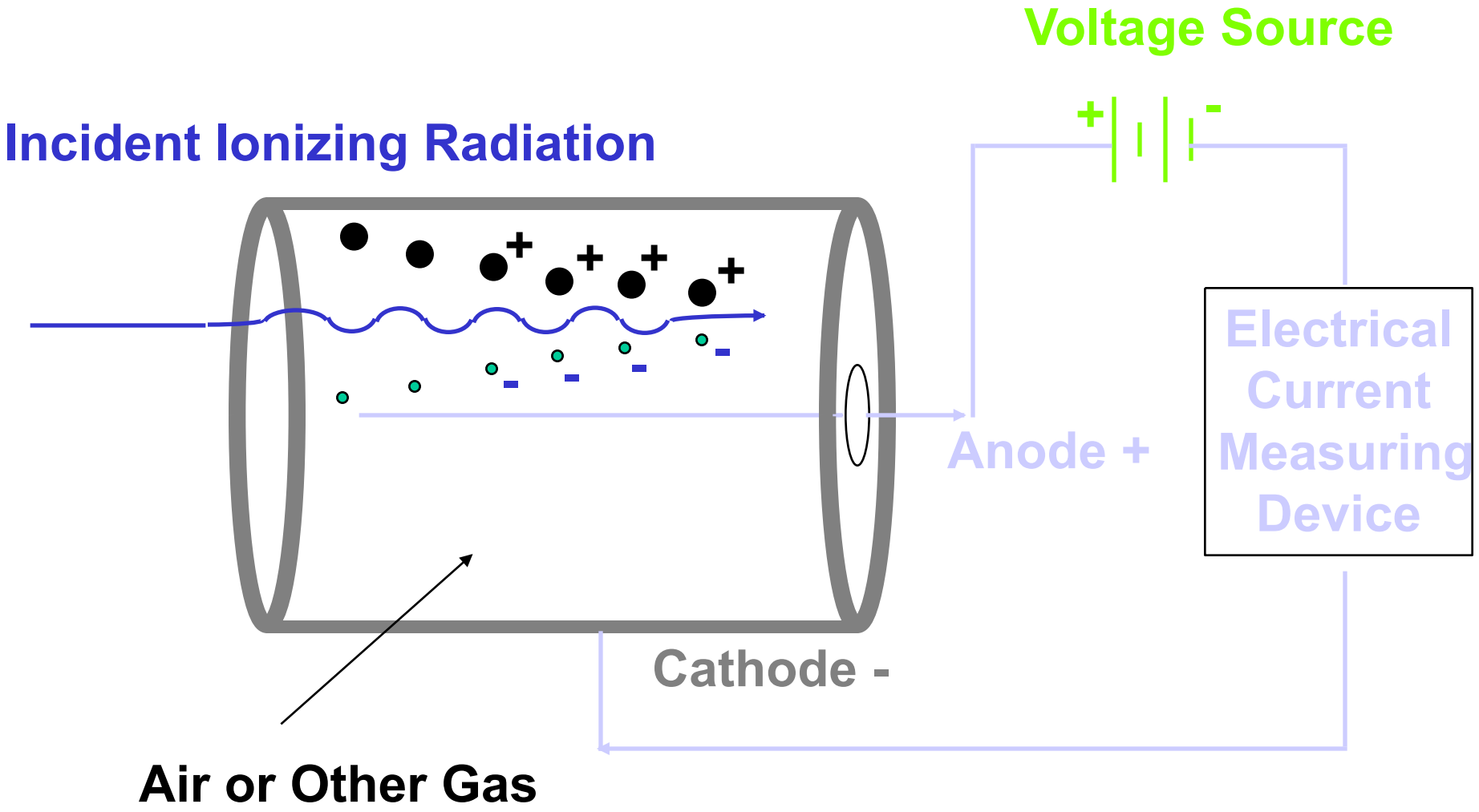
- Activity: The quantity of radioactive material present at a given time:
  - Curie (Ci) : 3.7×10^{10} disintegration per second (dps)
  - milliCurie (mCi): 3.7×10^{7} dps
  - microCurie (mCi): 3.7×10^{4} dps
  - picoCuries (pCi): .037 dps
  - Becquerel (Bq): 1 dps

Half-Life

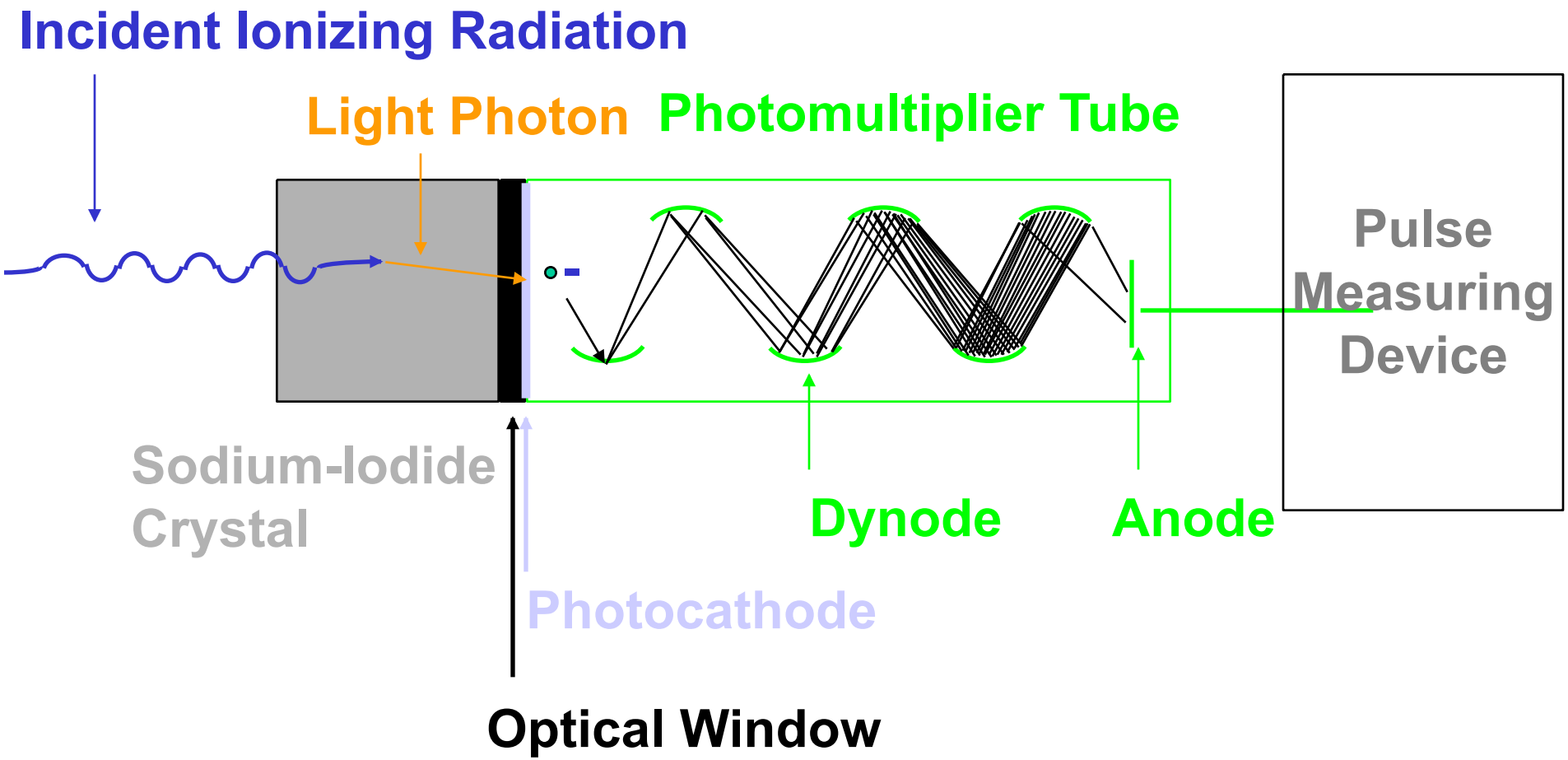
The time required for the amount of radioactive material to decrease by one-half



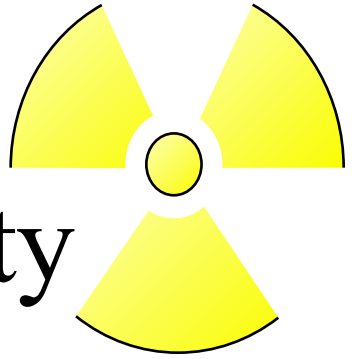
Radiation Detection
Gas Filled Detectors



Radiation Detection
Scintillation Detectors

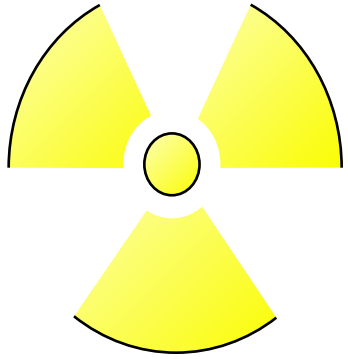


Radiation and Radioactivity



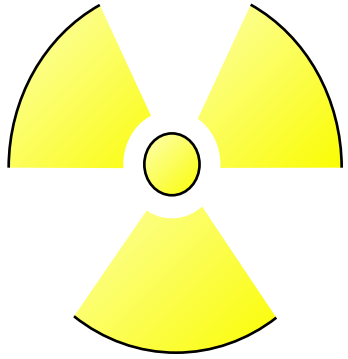
- Radiation: Energy in transit, either as particles or electromagnetic waves
- Radioactivity: The characteristic of various materials to emit ionizing radiation
- Ionization: The removal of electrons from an atom. The essential characteristic of high energy radiations when interacting with matter.

Radiation Units



- Roentgen: A unit for measuring the amount of gamma or X rays in air
- Rad: A unit for measuring absorbed energy from radiation
- Rem: A unit for measuring biological damage from radiation

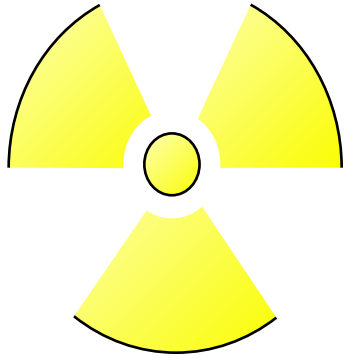
Elements



An element is the smallest amount of a substance that still exhibits the properties of that substance.

Elements are classified by the number of protons in each atom, and can be arranged in order in the Periodic Chart.

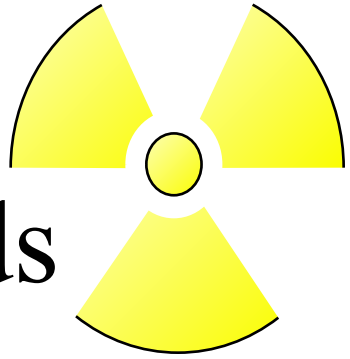
Atoms



Atoms are the building blocks of all matter, made up of protons and neutrons and electrons.

Almost all atoms are very stable, but some may have too much energy and be radioactive.

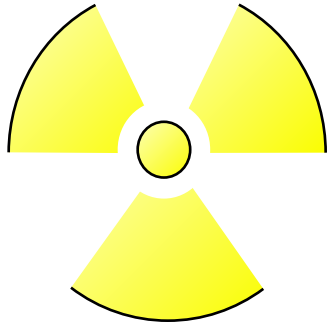
Molecules and Compounds



Atoms group together or bond to each other forming molecules and compounds.

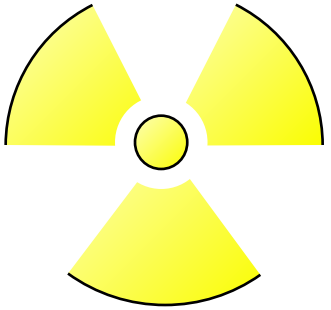
Examples of these are water (2 hydrogen, 1 oxygen atoms) and sugar (6 carbon, 12 hydrogen and 6 oxygen atoms)

Three States of Matter



- Solid: Solids are items don't change their shapes like rocks, wood and ice.
- Liquid: Liquids flow, like water, alcohol and glass
- Gas: Gases are free flowing, like air, oxygen and steam.

  The difference between each is the amount of energy the molecules have

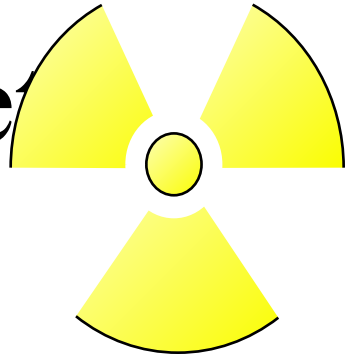


Electromagnetic Waves

Electromagnetic waves are energy waves, ranging from the low energy radio waves to the high energy gamma rays.

They have a height (amplitude) and a length between wave peaks (wave length)

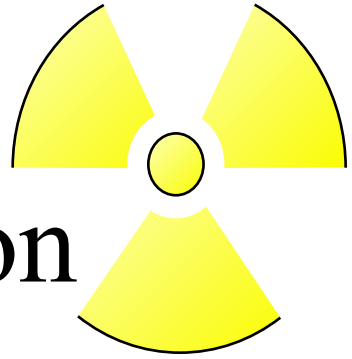
Non-Ionizing Electromagnetic Radiation



Non-Ionizing Electromagnetic Radiations do not have enough energy to remove electrons from atoms, such as:

- Ultraviolet Radiation
- Light
- Infrared Radiation
- Microwaves
- Radio Waves

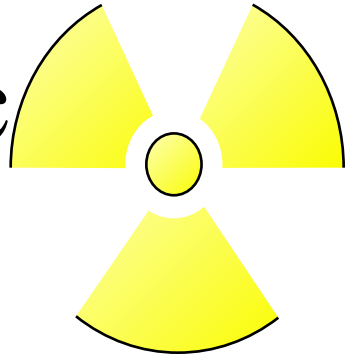
Contamination vs Radiation



Radiation and Contamination are often confused. Radiation is energy, while contamination is the physical presence of a radioactive material on something.

So, you may have contamination on your shoe, but not radiation.

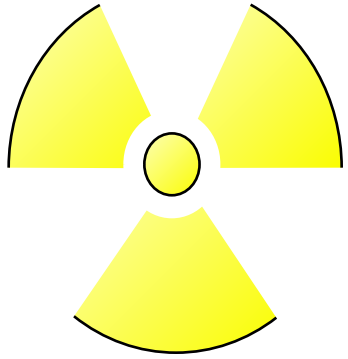
Ionizing Electromagnetic Radiation



Ionizing Electromagnetic Radiations do have enough energy to remove electrons from atoms, such as:

- X-rays
- Gamma rays

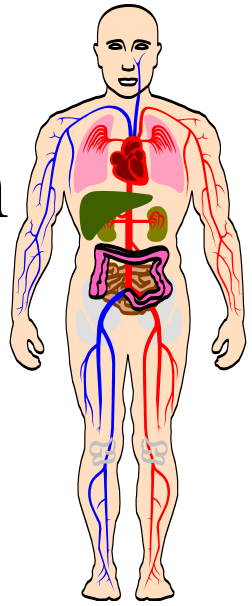
Units of Contamination



Contamination, or the presence of radioactive material on something is measured as count on a detector per some time like a minute (cpm), or by the actual decay rate (dps).

Radiation Effects and Risk

- Exposure: A measure of ionization in air from x-ray and gamma rays.
  - Roentgens, or mR
- Dose: A measure of the energy absorbed in any material as a radiation passes through it.
  - Rads or mrads, Gray or mGy.
- Dose equivalent: A measure of "risk"



Activities or Effects of Radiation Dose

- Food Irradiation:
  100000 rads
- Cancer Radiation Therapy:
  6000 rads
- Lethal WB Dose to 50% of Population:
  350 rads
- Increase risk of cancer by 1%
  12.5 rem
- Maximum Annual Occupational Dose:

Radiation Known to Occur at High Doses

- Non-Stochastic Effects: A health effect where the severity of the effect increases with dose:
  - Cataracts
  - Sterility
  - Loss of Hair (Epilation)
  - Skin Reddening (Erythema)
  - Acute Radiation Syndrome

Cancer and Cancer Risk

- Each year 1,000,000 cancers are diagnosed in the U.S.
- Cancer is the second leading cause of death in the U.S. Approximately 1 in 6 will die of cancer.
- Radiation exposure does not cause unique forms of cancer.
- The risk of cancer from radiation exposure is assumed to be linear with dose (ICRP

Radiation and Risk
Perceptions and Reality

Public	**1**	**Nuclear Power**
	2	**Motor Vehicles**
	3	**Handguns**
	4	**Smoking**
	5	**Motorcycles**
	6	**Alcoholic Beverages**
	7	**Private Aviation**
	8	**Police Work**
	9	**Pesticides**
	10	**Surgery**
	11	**Fire Fighting**
	12	**Large Construction**
	13	**Hunting**
	14	**Spray Cans**
	15	**Mountain Climbing**

Radiation and Risk: Perceptions and Reality

Public

16	Bicycles
17	Commercial Aviation
18	Electric Power
19	Swimming
20	Contraceptives
21	Skiing
22	X-Rays
23	High School and College Football
24	Railroads
25	Food Preservatives
26	Food Coloring
27	Power Mowers
28	Prescription Antibiotics
29	Home Appliances
30	Vaccinations

Radiation and Risk: Perceptions and Reality

Public			Experts
1	Nuclear Power	20	
2	Motor Vehicles	1	
3	Handguns	4	
4	Smoking	2	
5	Motorcycles	6	
6	Alcoholic Beverages	3	
7	Private Aviation	12	
8	Police Work	17	
9	Pesticides	8	
10	Surgery	5	
11	Fire Fighting	18	
12	Large Construction	13	
13	Hunting	23	
14	Spray Cans	26	
15	Mountain Climbing	29	

Radiation and Risk: Perceptions and Reality

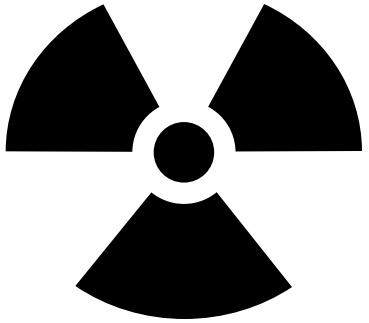
Public		Experts
16	Bicycles	15
17	Commercial Aviation	16
18	Electric Power	9
19	Swimming	10
20	Contraceptives	11
21	Skiing	30
22	X-Rays	7
23	High School and College Football	27
24	Railroads	19
25	Food Preservatives	14
26	Food Coloring	21
27	Power Mowers	28
28	Prescription Antibiotics	24
29	Home Appliances	22
30	Vaccinations	25

Days of Life Lost from Various Risks

Being an unmarried male	**3,500**
Smoking cigarettes and male	**2,250**
Heart disease	**2,100**
Being an unmarried female	**1,600**
Being 30 percent overweight	**1,300**
Cancer	**980**
Being 20 percent overweight	**900**
Having only an 8th grade education	**850**
Smoking and being female	**800**
Being poor	**700**
Stroke	**520**
Having a dangerous job	**300**
Driving a car	**207**
Pneumonia, Flu	**141**
Alcohol	**130**
Accidents in the home	**95**
Suicide	**95**
Diabetes	**95**

Days of Life Lost from Various Risks

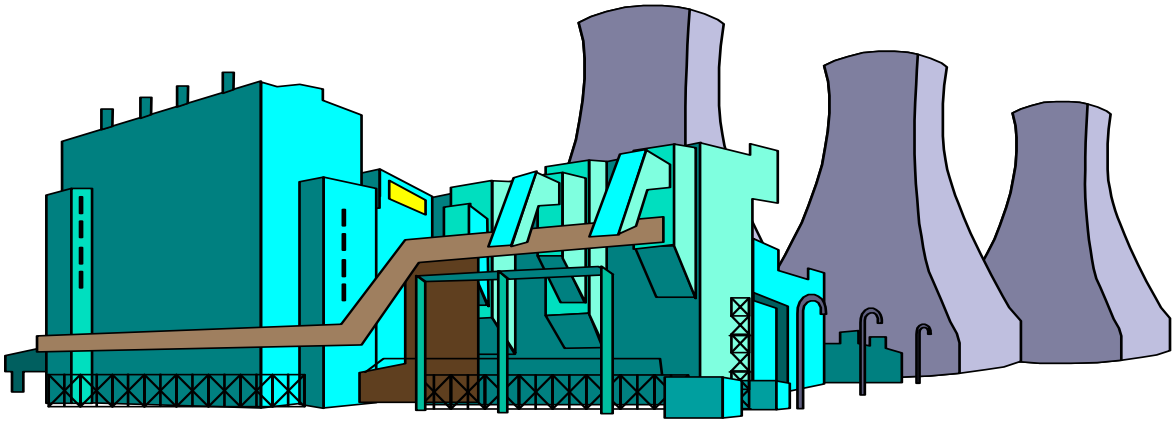
Being Murdered	**90**
Having an average risk job	**74**
Drowning	**41**
Having a job with radiation exposure	**40**
Falls	**39**
Walking down the street	**37**
Having a safe job	**30**
Fires and burns	**27**
Using illegal drugs	**18**
Poisoning	**17**
Suffocation	**13**
Natural Radiation	**8**
Medical X-Rays	**6**
Coffee	**6**
Oral contraceptives	**5**
Riding a bike	**5**
Drinking Diet Sodas	**2**
Radiation from Nuclear Industry	**0.02**



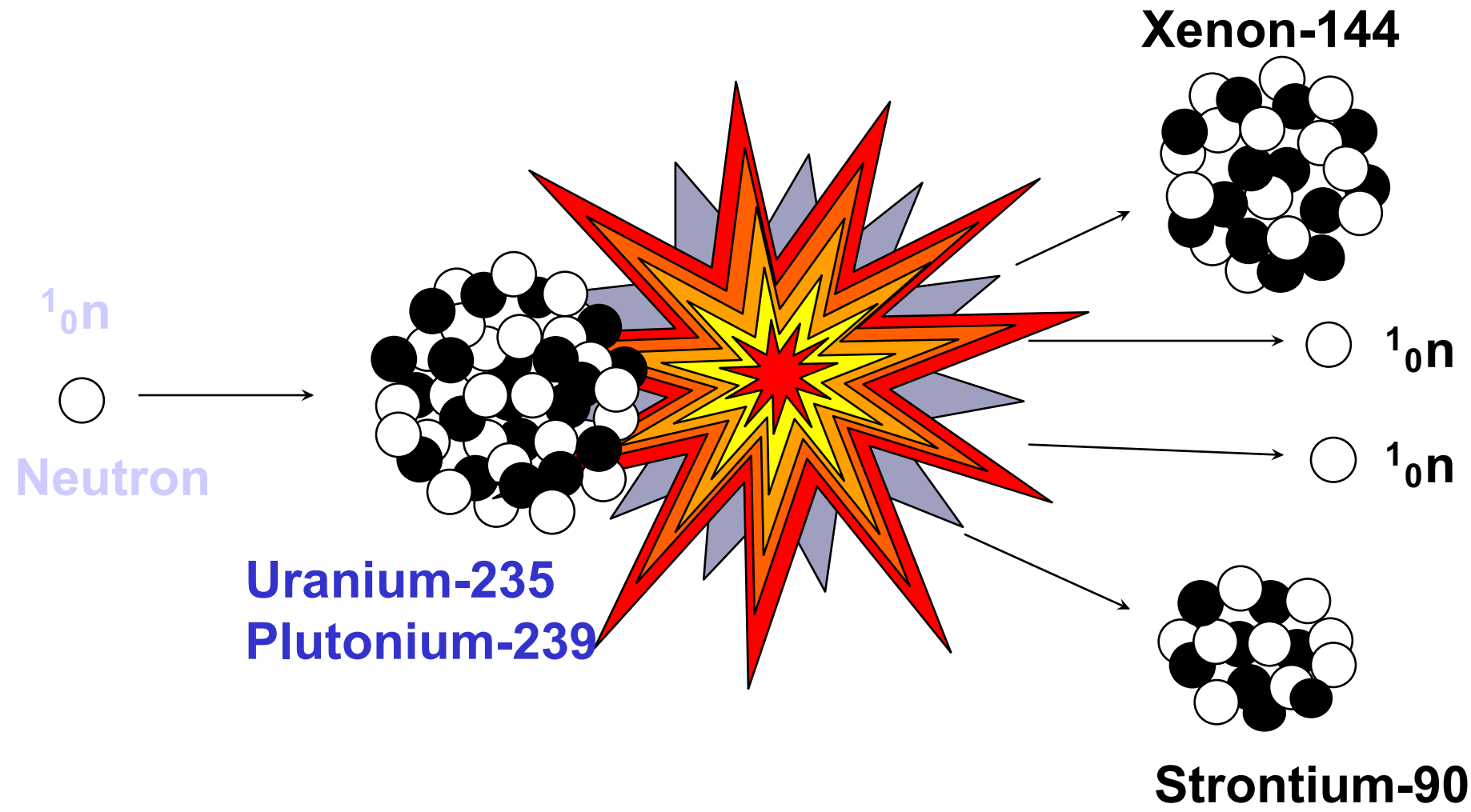
Activities which increase risk by 1 in a Million

Smoking 1.4 Cigarettes	**Cancer, heart disease**
Drinking 0.5 liter of wine	**Cirrhosis of the liver**
Spending 1 hour in a coal mine	**Black lung disease**
Spending 3 hours in a coal mine	**Accident**
Living two days in Boston or New York	**Air Pollution**
Traveling 10 miles by bicycle	**Accident**
Traveling 150 miles by car	**Accident**
Flying 1000 miles by jet	**Accident**
Flying 6000 miles by jet	**Cancer caused by cosmic radiation**
Living two months in Denver	**Cancer caused by cosmic radiation**
Living two months in brick building	**Cancer caused by natural radiation**
One chest x-ray	**Cancer caused by radiation**
Eating 40 Tablespoons of peanut butter	**Liver cancer caused by aflatoxin B**
Living 5 years at site boundary of a nuclear plant	**Cancer caused by radiation**
Eating 100 charcoal -broiled steaks	**Cancer from benzopyrene**
Living within 5 miles of a nuclear reactor for 50 years	**Cancer caused by accidental radiation release**

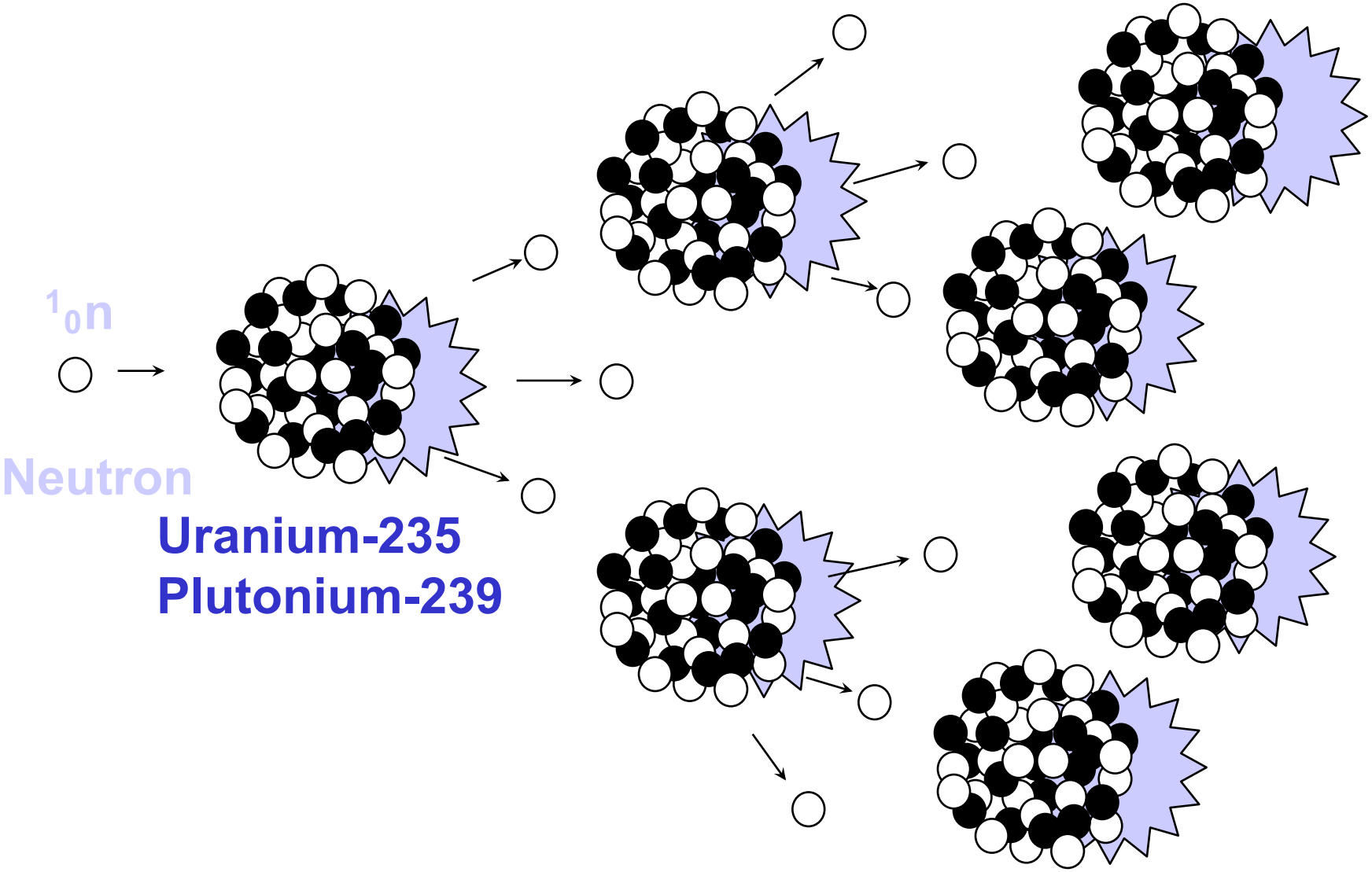
Nuclear Power



Fission

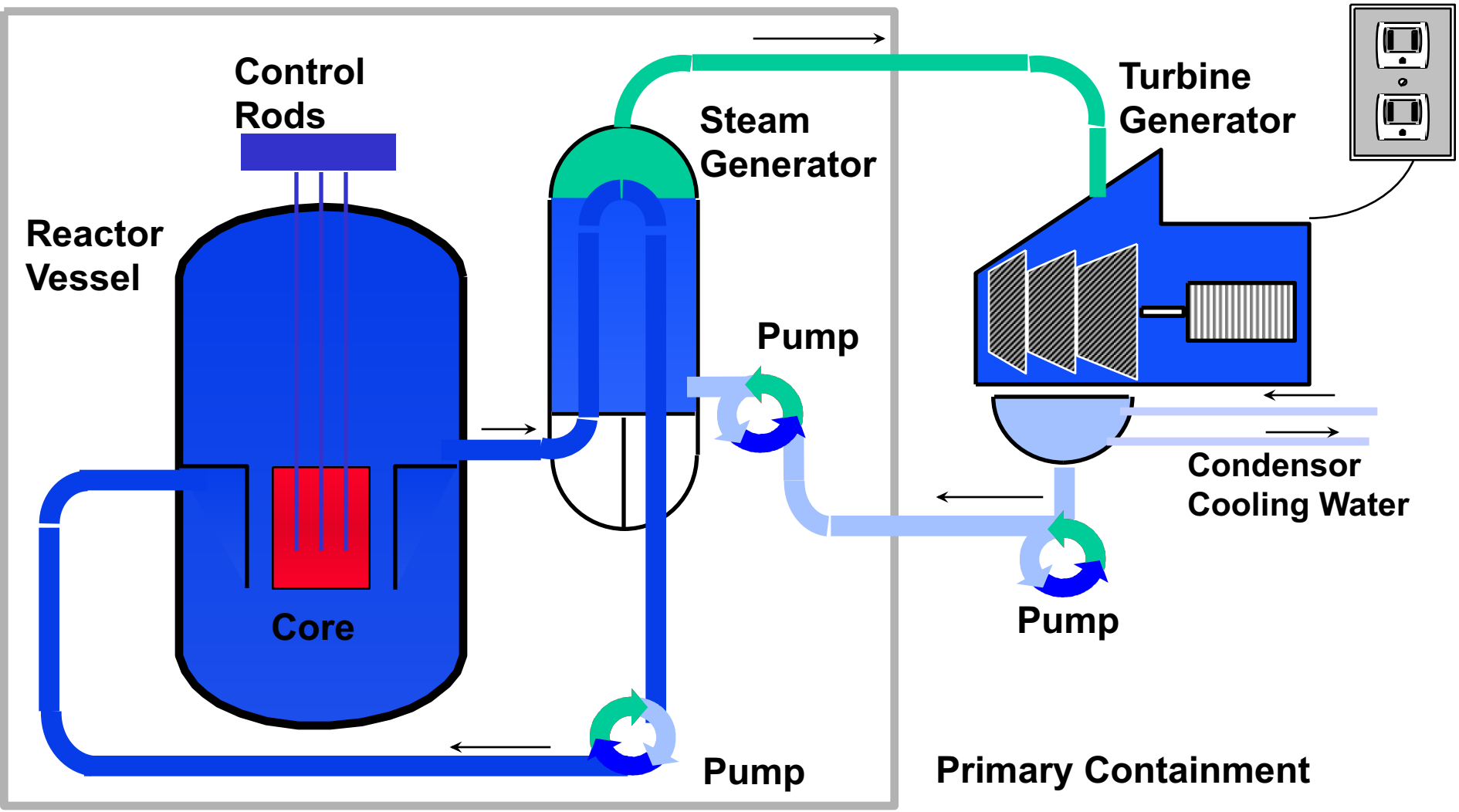

Xenon-144
$^1_0$n
Neutron
$^1_0$n
$^1_0$n
Uranium-235
Plutonium-239
Strontium-90

Fission Chain Reactions

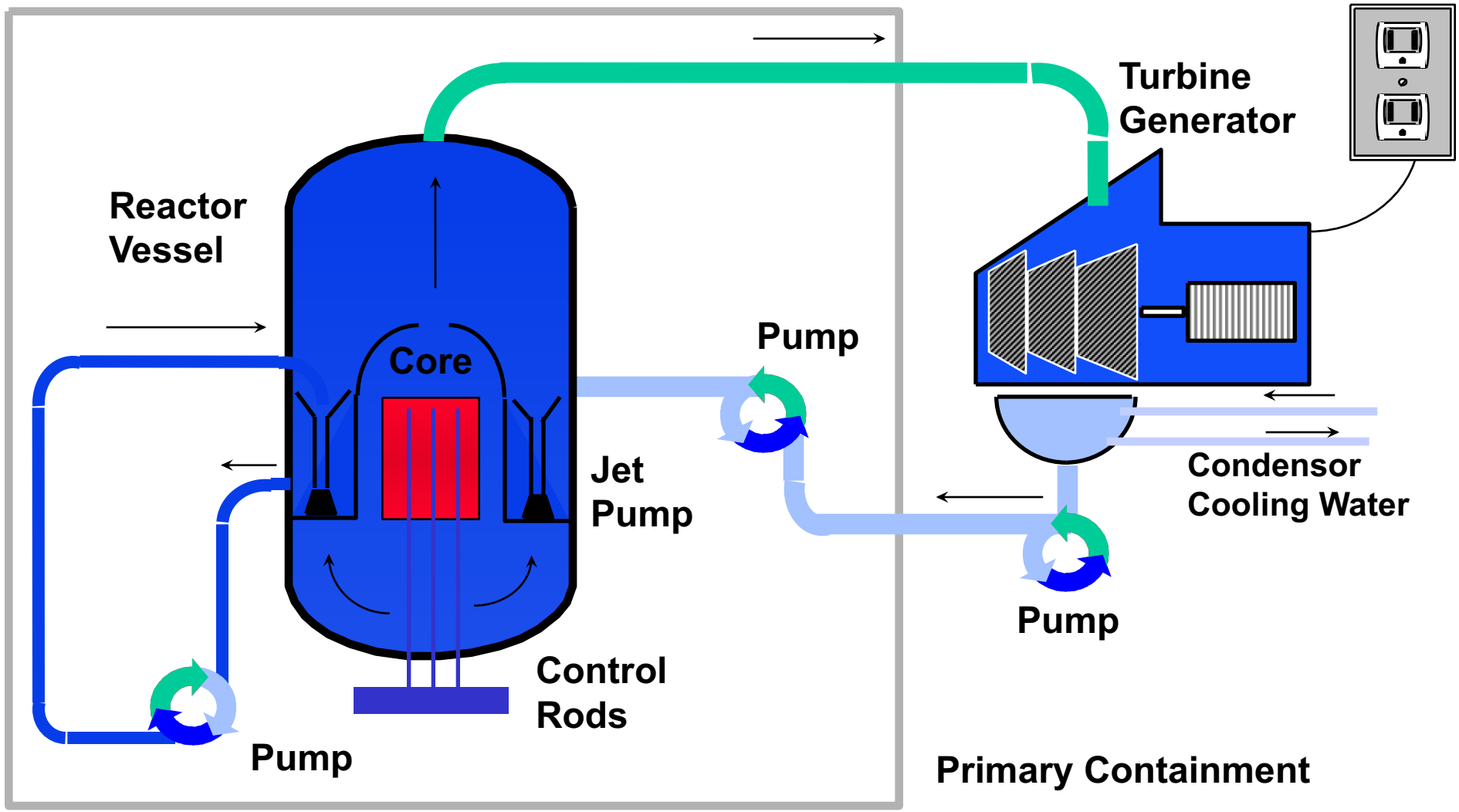


Basic Design of a Reactor Core

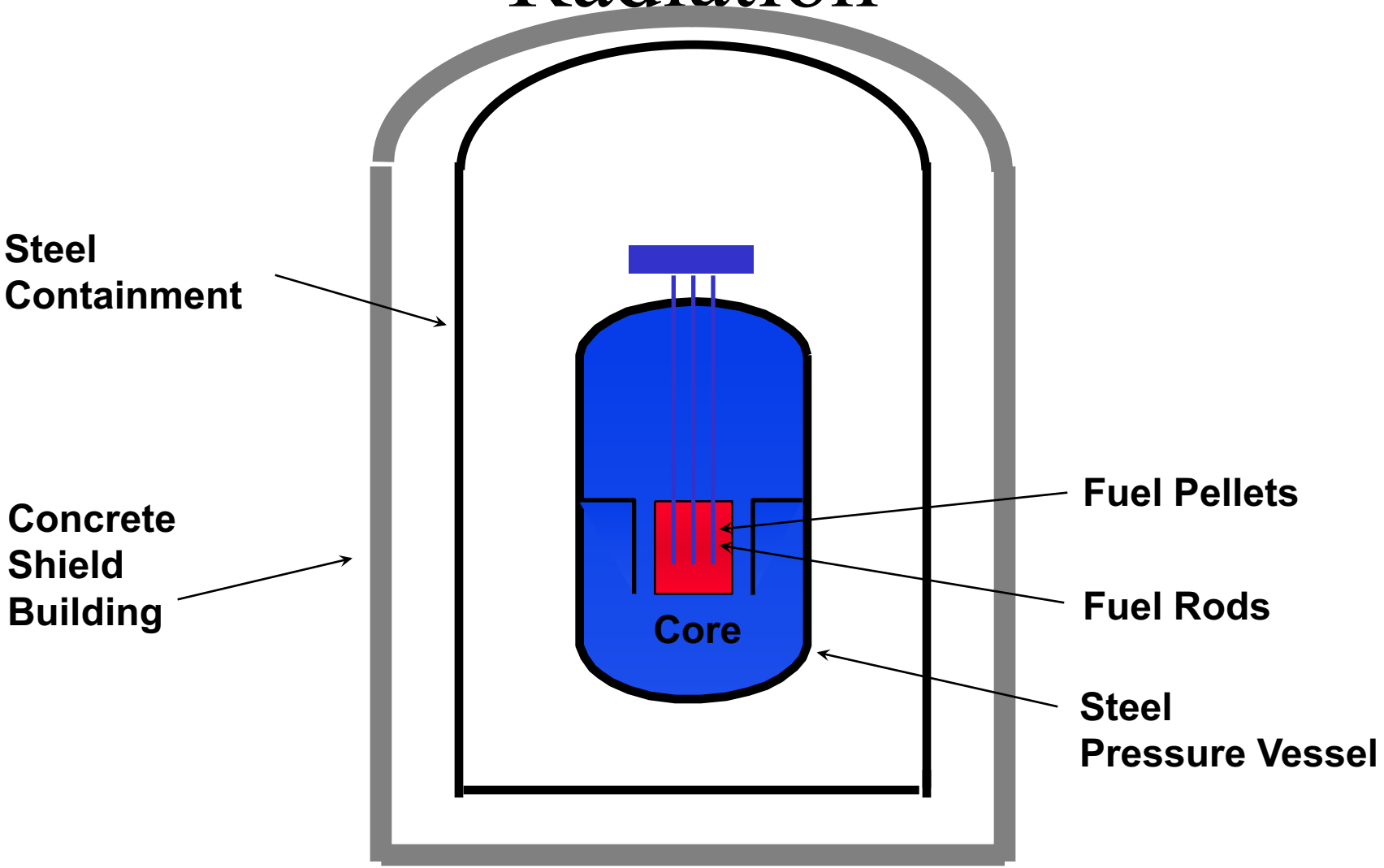
Pressurized Water Reactor



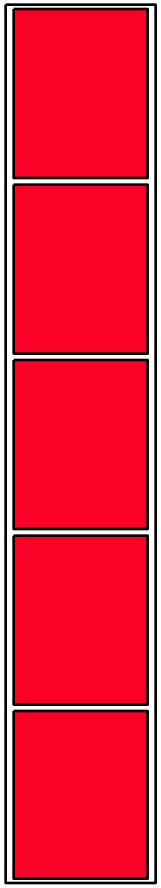
Boiling Water Reactor



Barriers Against Release of Radiation

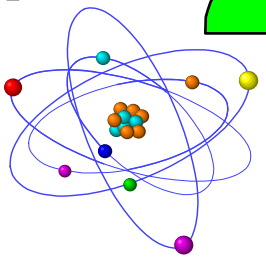


A crayon* (without the tip) is about the size of five uranium fuel pellets stacked together

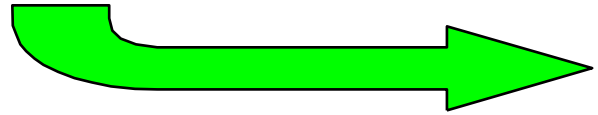


Source Energy Equivalents

Five uranium fuel pellets ..



have as much energy available in todays nuclear power plants as...

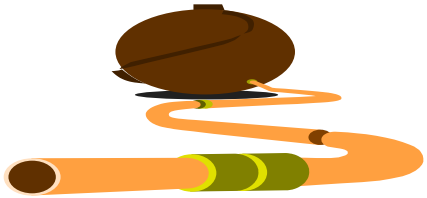


85,000 cu ft of natural gas

15 Barrels of oil

12 1/2 Tons of wood

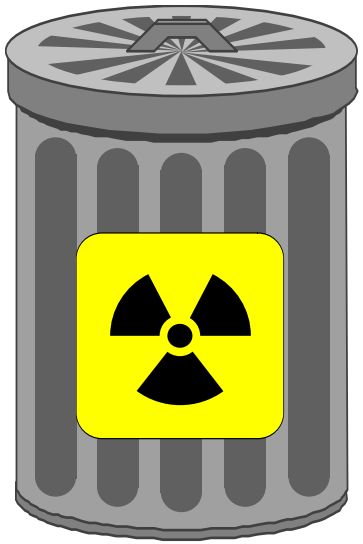
5 Tons of coal

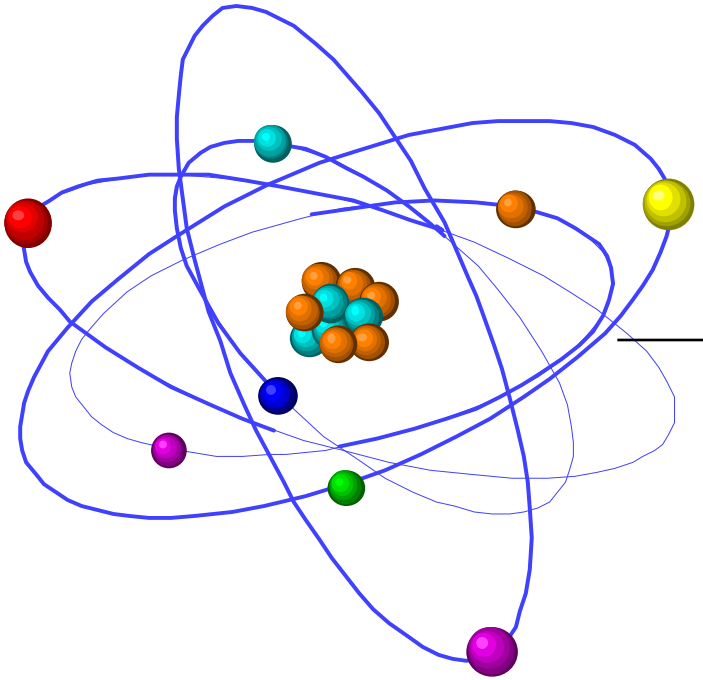


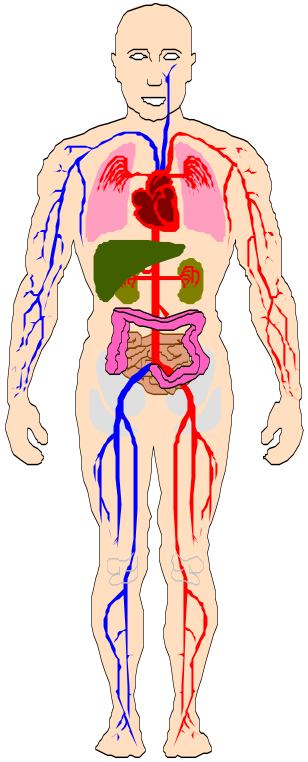
* Crayons are not radioactive nor are they used as nuclear fuel

IONIZING RADIATION

School Presentation



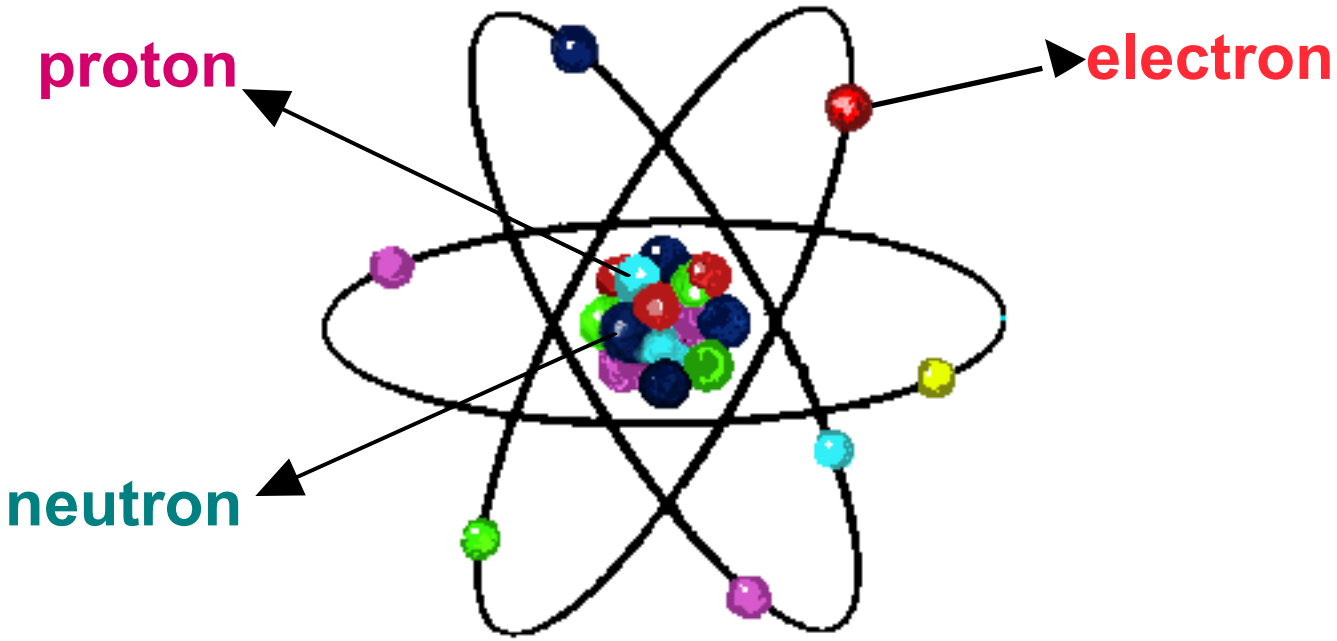




What Will You Learn Today?

- Identify natural background and manufactured sources of radiation.
- Learn how radiation affects living things.
- Learn how radiation is detected using radiation survey meters

The three basic particles of the atom are PROTONS, NEUTRONS AND ELECTRONS



UNSTABLE atoms emit energy

RF μwave infrared visible uv x-ray γ-ray cosmic

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low energy

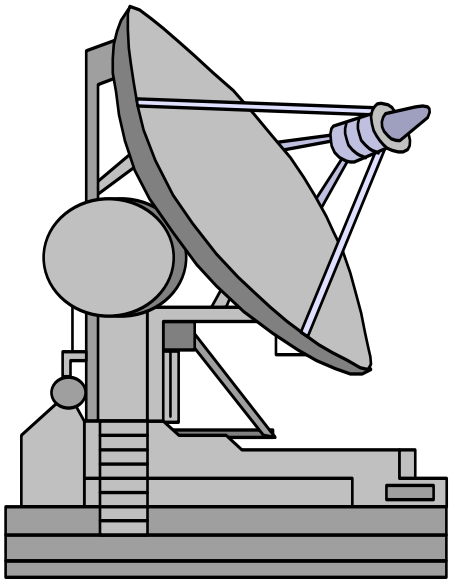
non-ionizing

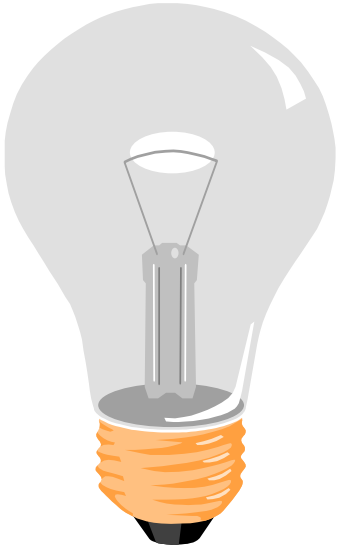
high energy

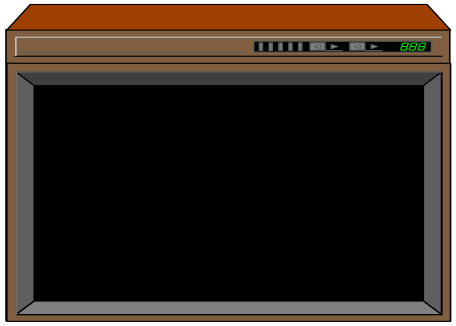
ionizing radiation

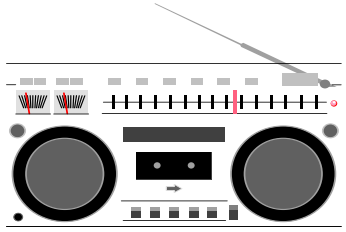
Non-Ionizing Radiation

Does not have enough energy to remove electrons from surrounding atoms



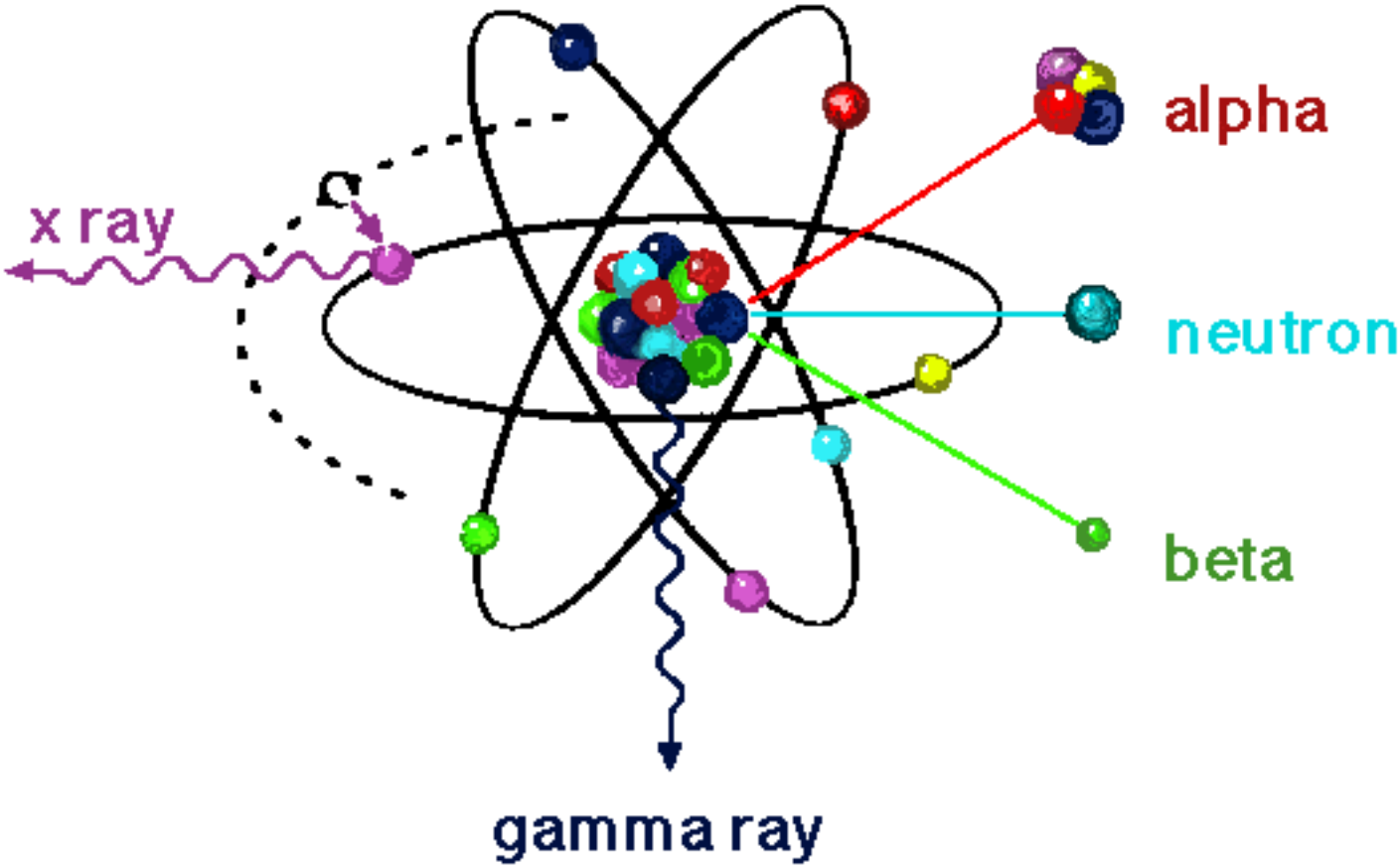






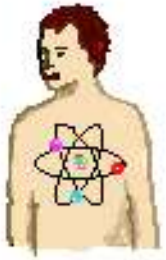
Ionizing Radiation -

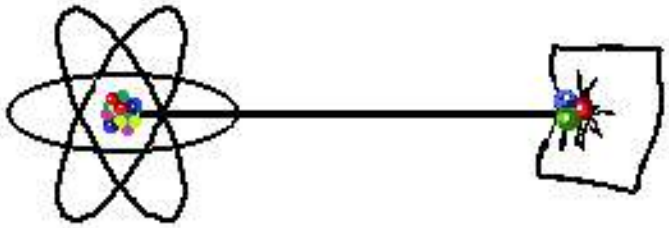
can deposit energy in neighboring atoms resulting in the removal of electrons.



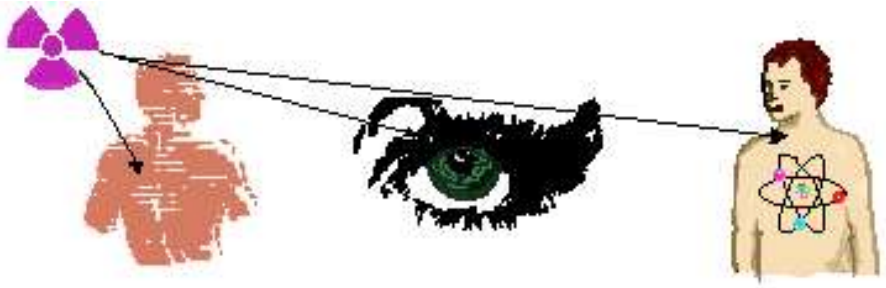
Alpha Radiation is only a hazard when inside your body (internal hazard)

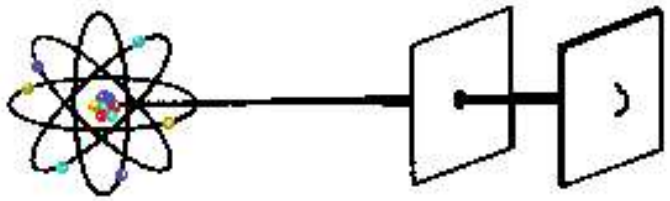
Your skin will stop it



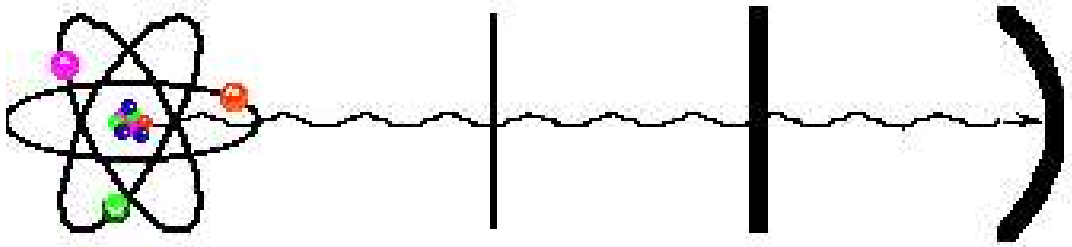


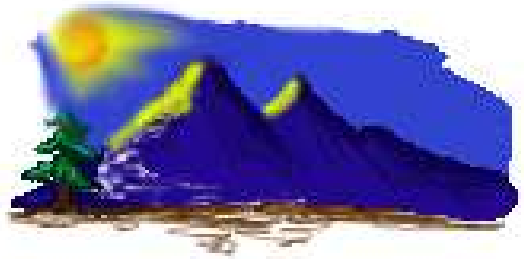
Beta Radiation is a Skin, Eye and Internal Hazard

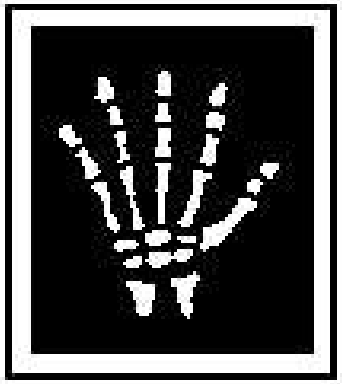




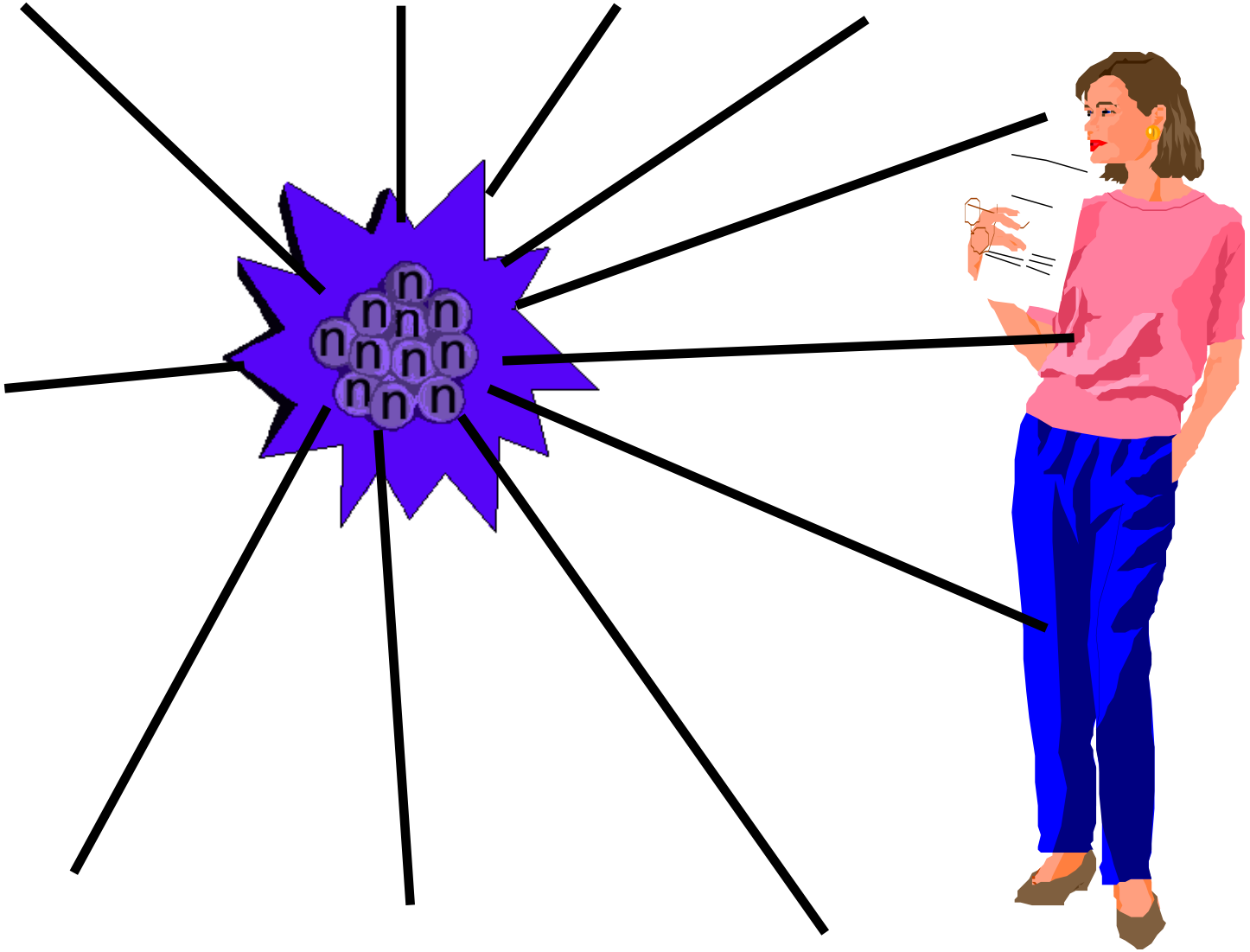
natural food, a





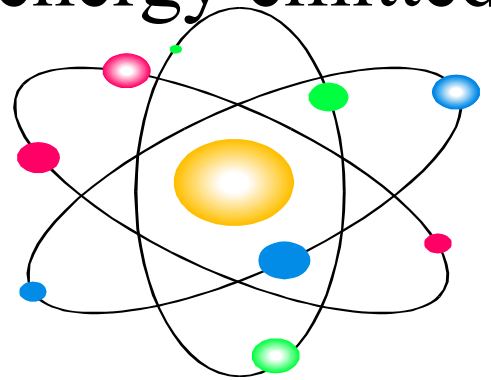


Neutron particles have no charge and can penetrate deep into the body

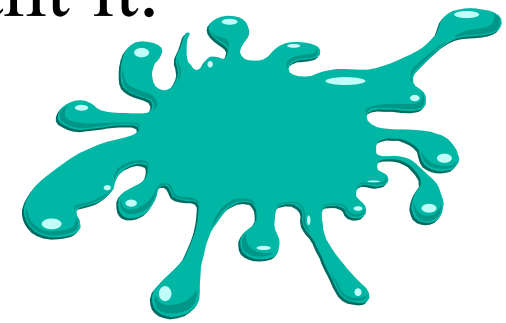


Radiation Versus Radioactive Contamination

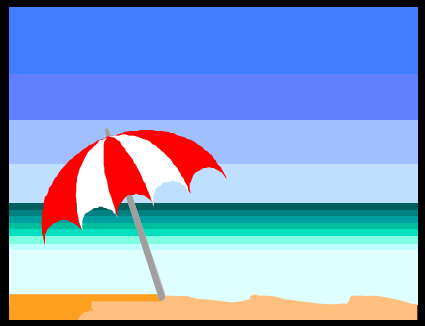
- Radiation is particles or waves of energy emitted from unstable atoms.

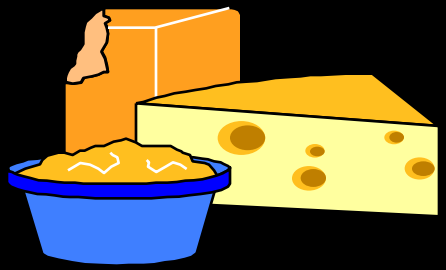


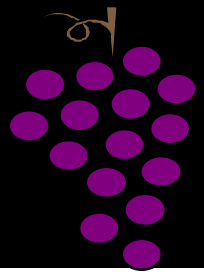
- Radioactive Contamination is radioactive material usually in any location you do not want it.

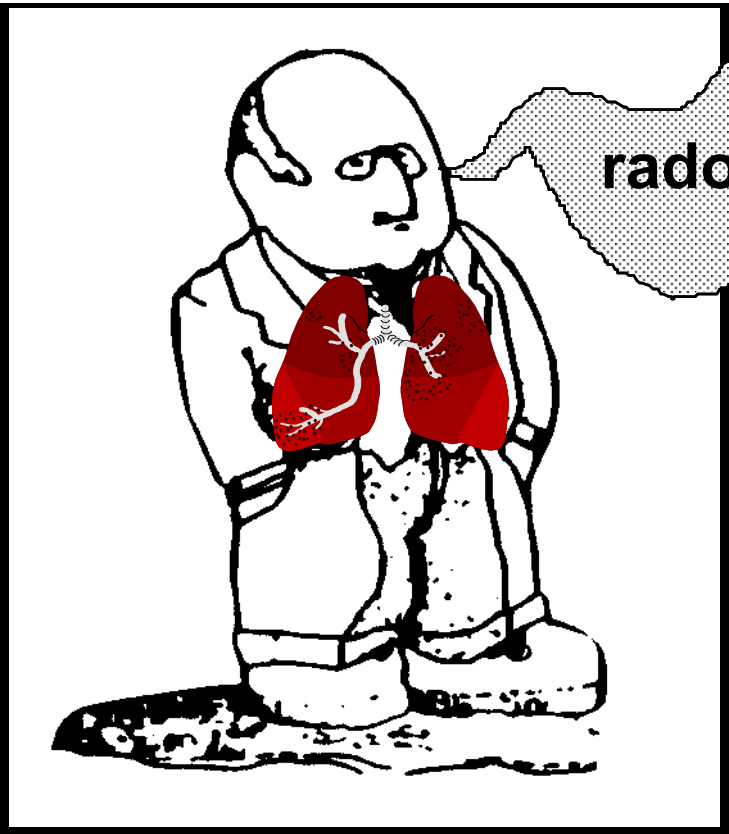


Background and Manufactured Radiation In the U.S. Contributes 360 mrem per Year



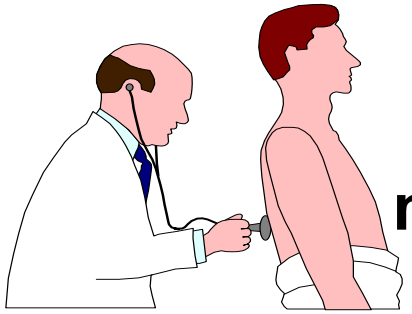






Manufactured sources of radiation contribute an average of 60 mrem/year

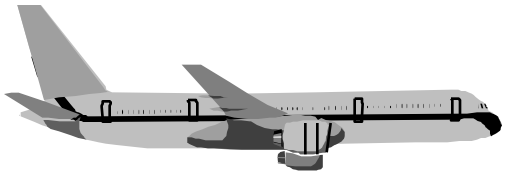
cigarette smoking - 1300 mrem

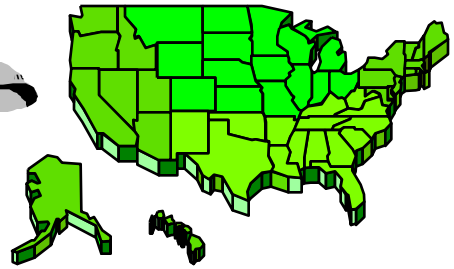


medical - 53 mrem

round trip US by air

5 mrem per trip





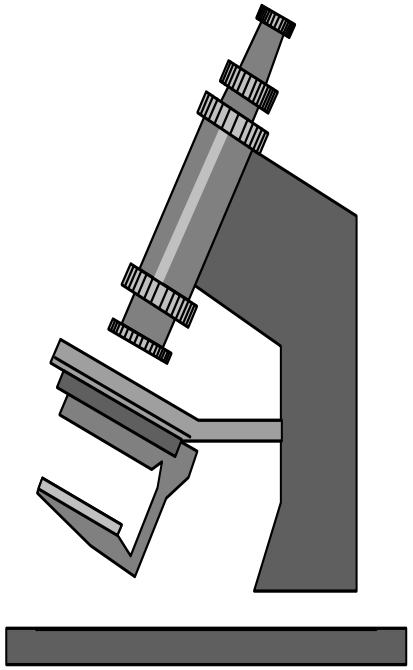
building materials - 3.6 mrem

smoke detectors - 0.0001 mrem

fallout < 1 mrem

Biological Effects of Radiation

- Early scientists determined that radiation was a useful tool but it could hurt you.
- Radiation can cause burns and cellular damage.



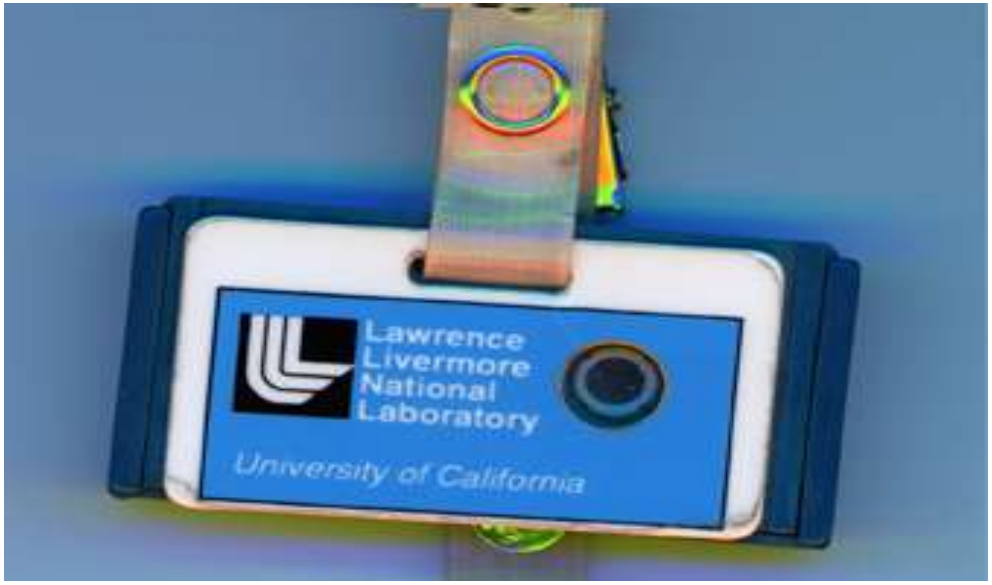
Biological Effects of Radiation

4 The principle hazard from radiation exposure is an increase in the risk of cancer induction.

SIGNS ARE REQUIRED TO NOTIFY EVERYONE OF THE PRESENCE OF RADIATION

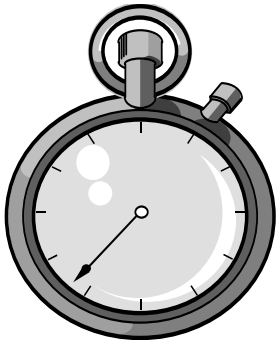
MONITORING RADIATION EXPOSURE

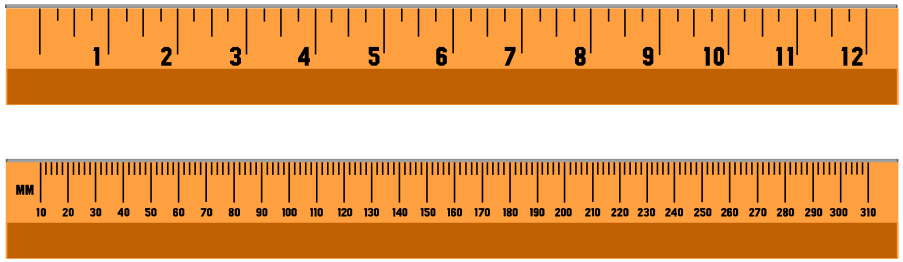
Radiation dosimeters measures radiation dose to people.

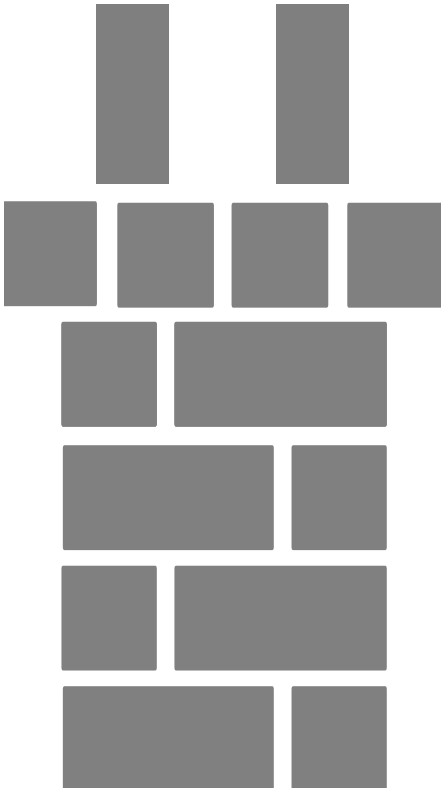


Minimize Dose By Good Practices

- TIME - reduce time of exposure
- DISTANCE - increase distance
- SHIELDING - use shielding

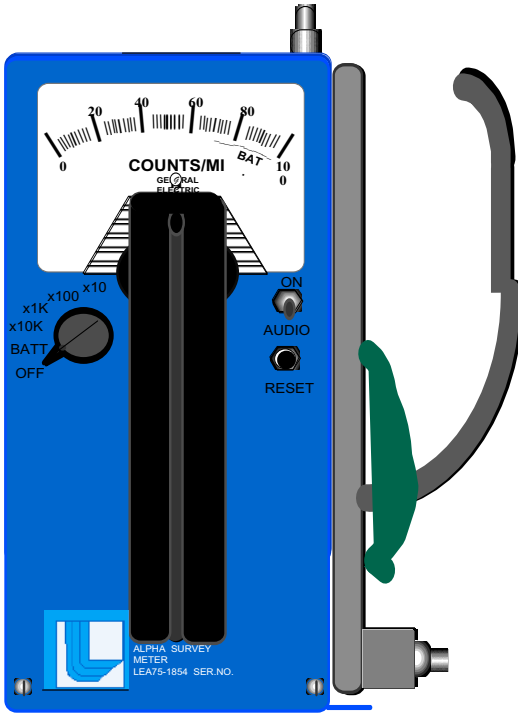




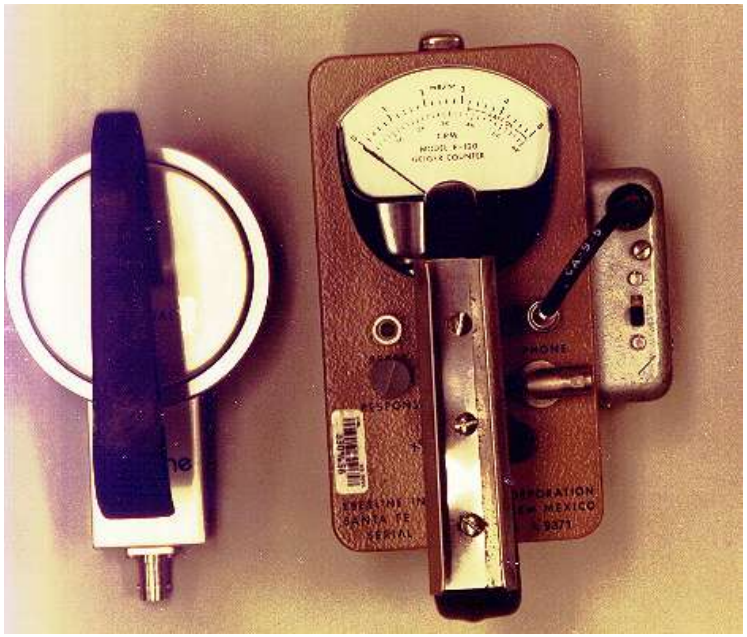


Radiation is detected with survey meters

Alpha Survey Meter



Beta, Gamma & X-ray Survey Meter



Solar Radiation

Cosmic Rays

Radiation and Life

Nuclear Medicine

X-Rays

Radon $^{4}_{2}\alpha^{++}$

Consumer Products

Each Other

Radioactive Waste

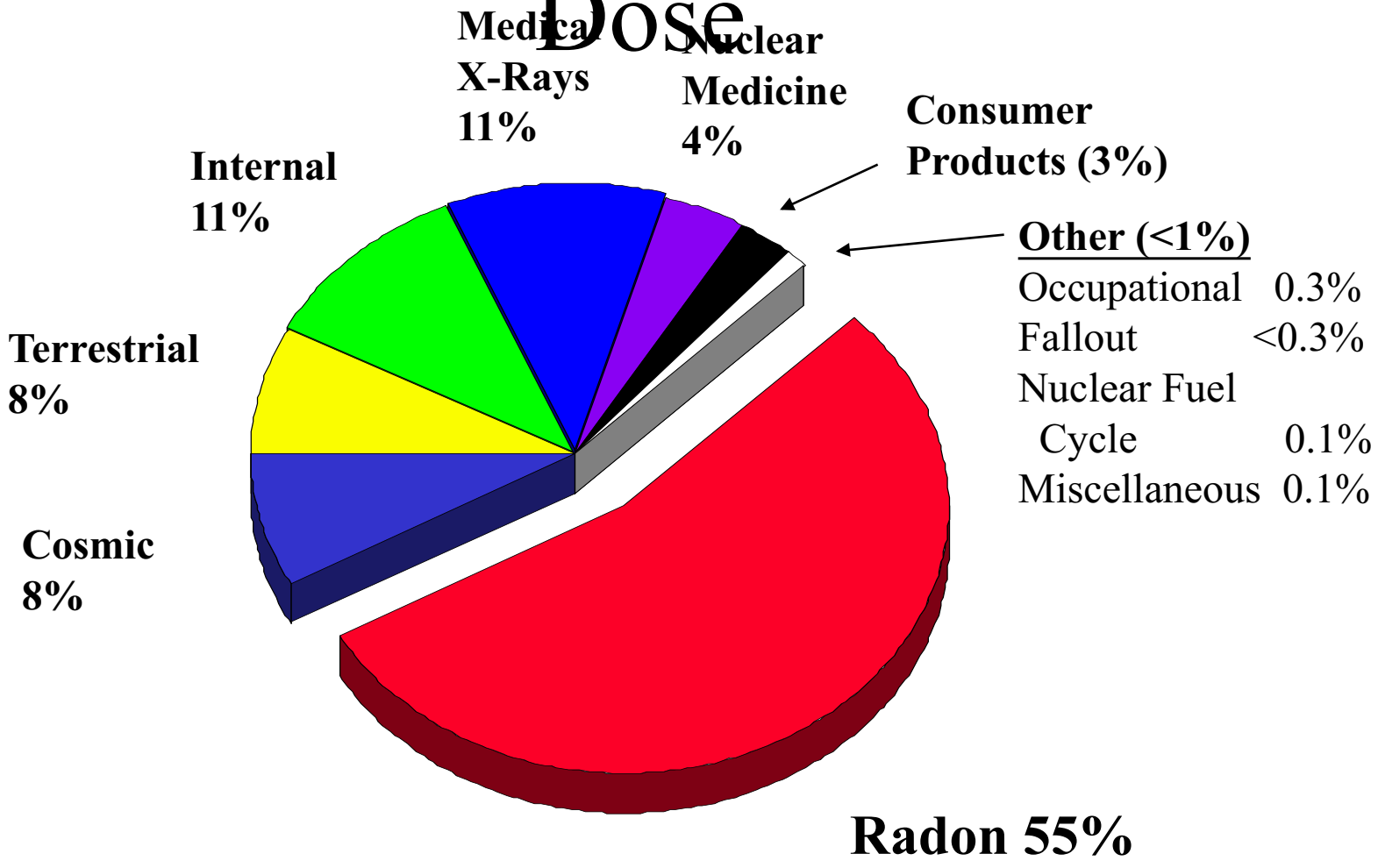
Nuclear Power

Terrestrial Radiation

Food & Drink

Milk

Contribution of Various Sources of Radiation to Average Annual Dose



Average Annual Effective Dose in U.S. Population, (1980-82)

- Natural Sources
  - Radon — **200 mrem**
  - Cosmic — **27 mrem**
  - Cosmogenic — **10 mrem**
  - Terrestrial — **28 mrem**
  - In the Body — **39 mrem**
- Occupational — **0.9 mrem**
- Nuclear Fuel Cycle — **0.05 mrem**
- Consumer Products — **---**
  - Tobacco — **5 - 13 mrem**
  - Other — **39 mrem**

14 mrem

Total Annual Dose = 360 mrem

← **Upto 16 rem to Bronchial epithelium (Lung lining)**

Early Uses of Radioactivity

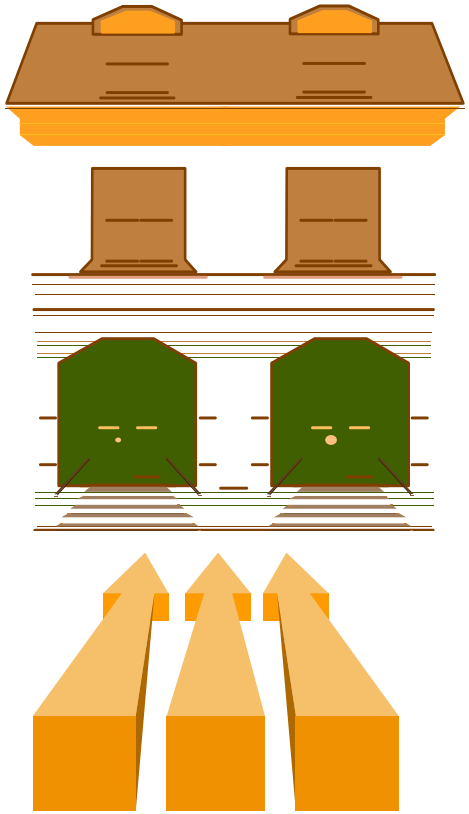
- Radiation Therapy
- Welsbach Thorium Gas Mantles
- Uranium Ceramic Glazes
- Anna Glass (Uranium Nitrate)
- Luminous Dials (Radium)
- Patent Radium Therapies
  - Radithor
  - Radium Poultices

Modern Uses of Small Amounts of Radioactive Material or Radiation

- Ophthalmic Glass
- Aerosol (Smoke) Detectors
- Airport Inspection Systems
- Lantern Mantles
- Fluorescent Lamp Starters
- Welding Rods
- Fluid Guages
- Check Sources

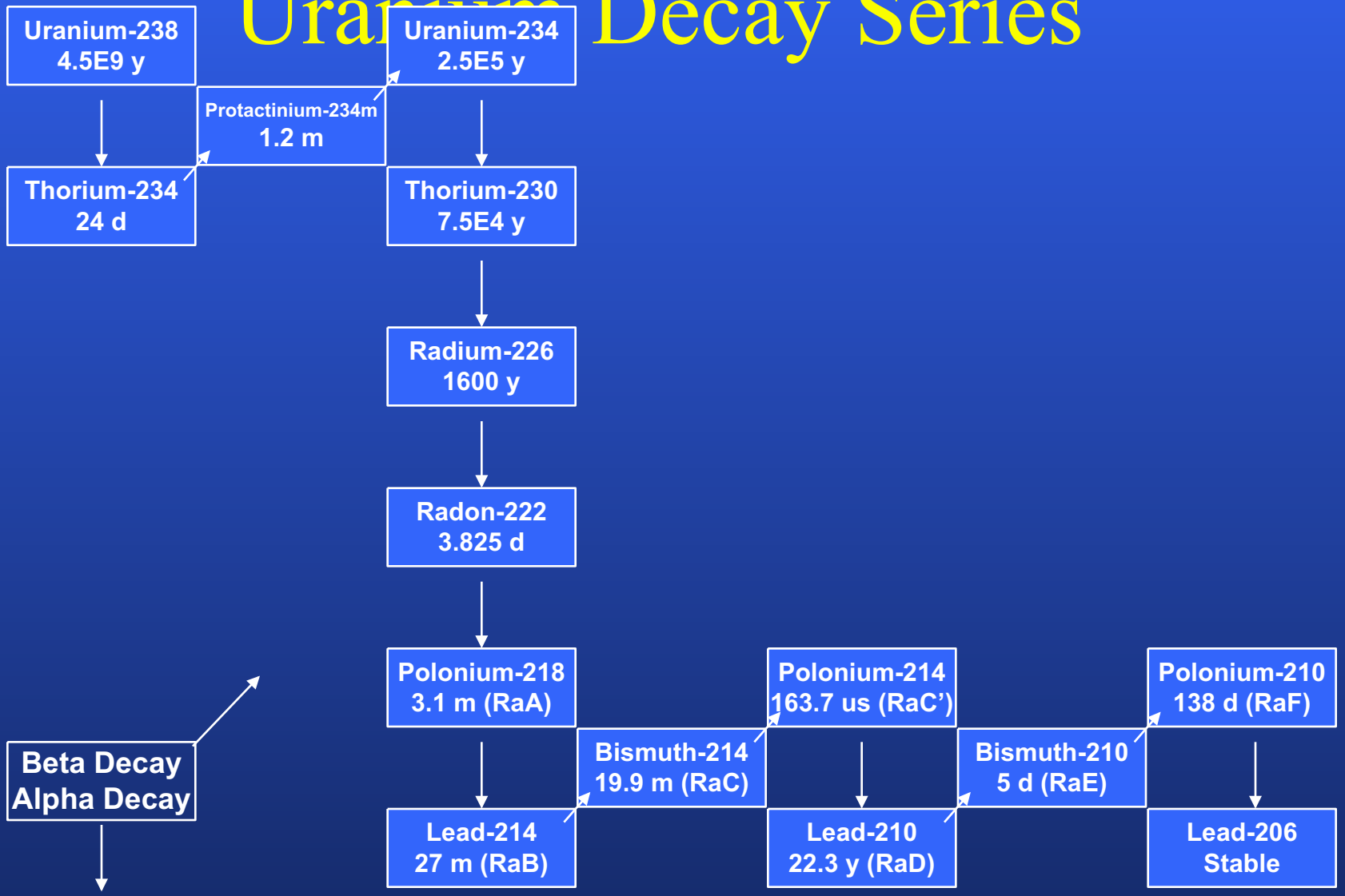
Modern Uses of Large Amounts of Radioactive Materials or Radiation

- Nuclear Power
- Nuclear Propulsion
- Nuclear Weapons
- Food and Medical Supply Irradiation
- Industrial Radiography
- Scientific Research
- Medical X-Rays
- Nuclear Medicine Services

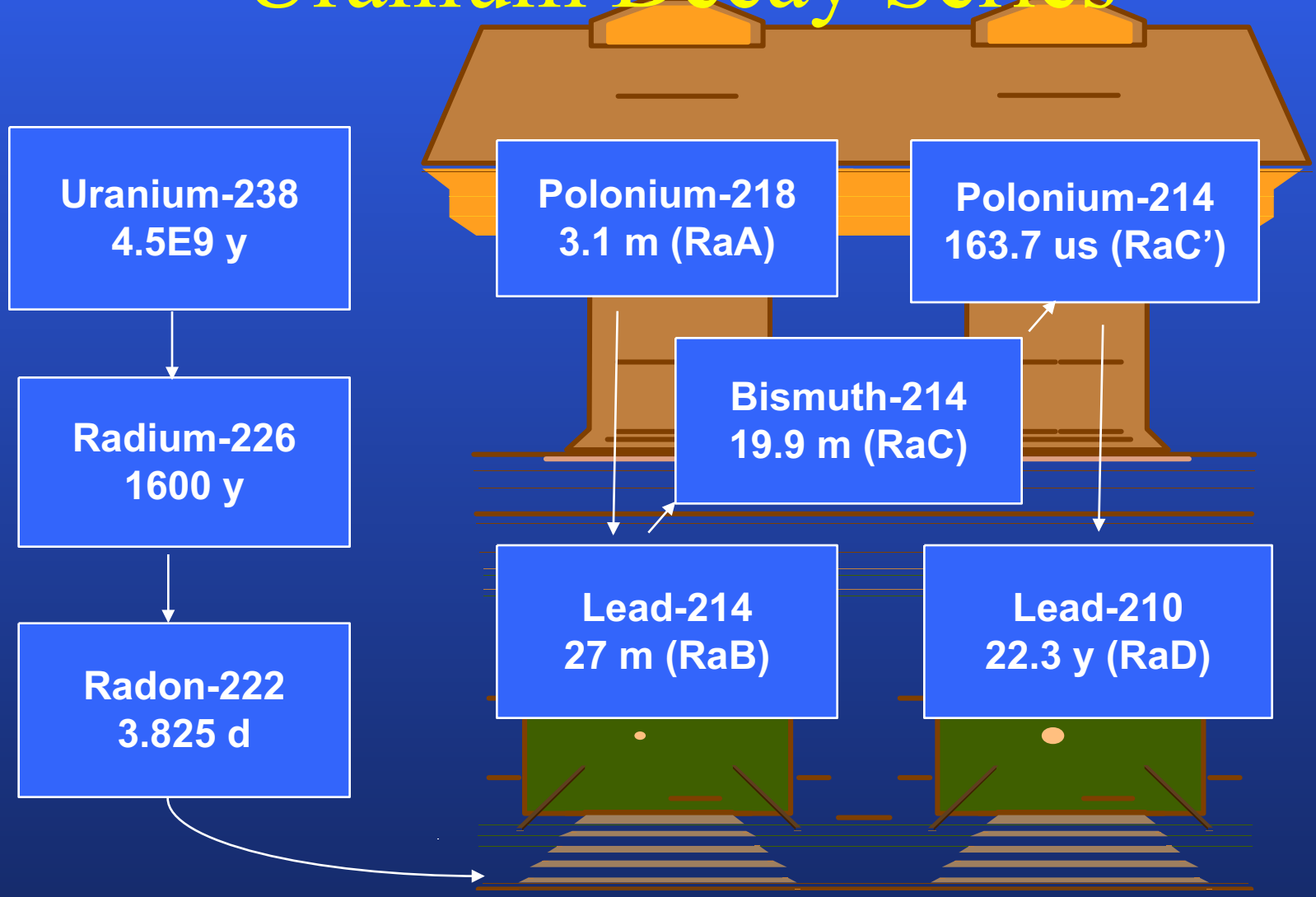


RADON and Life

Uranium Decay Series

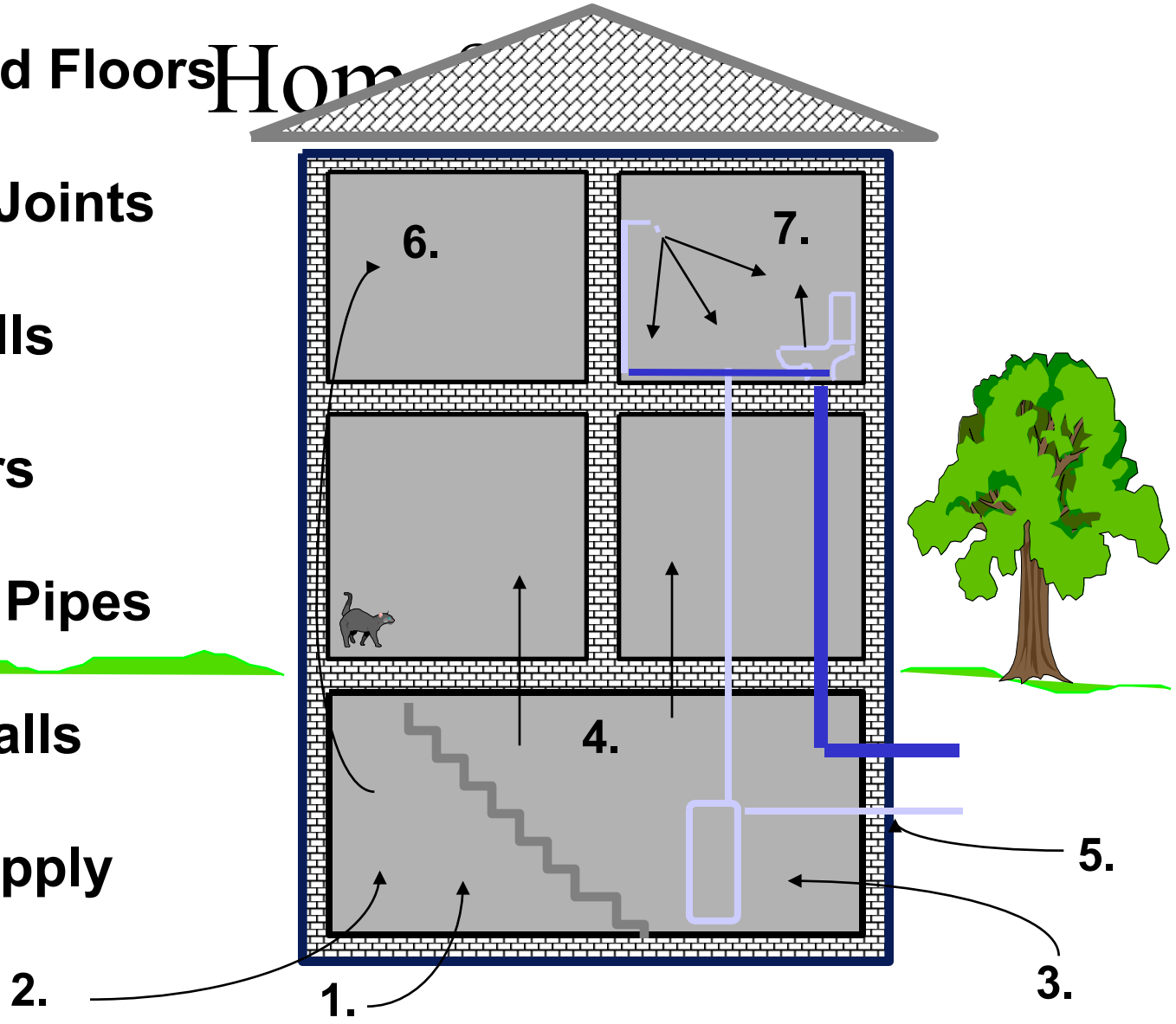


Uranium Decay Series



How Does Radon Get in the Home?

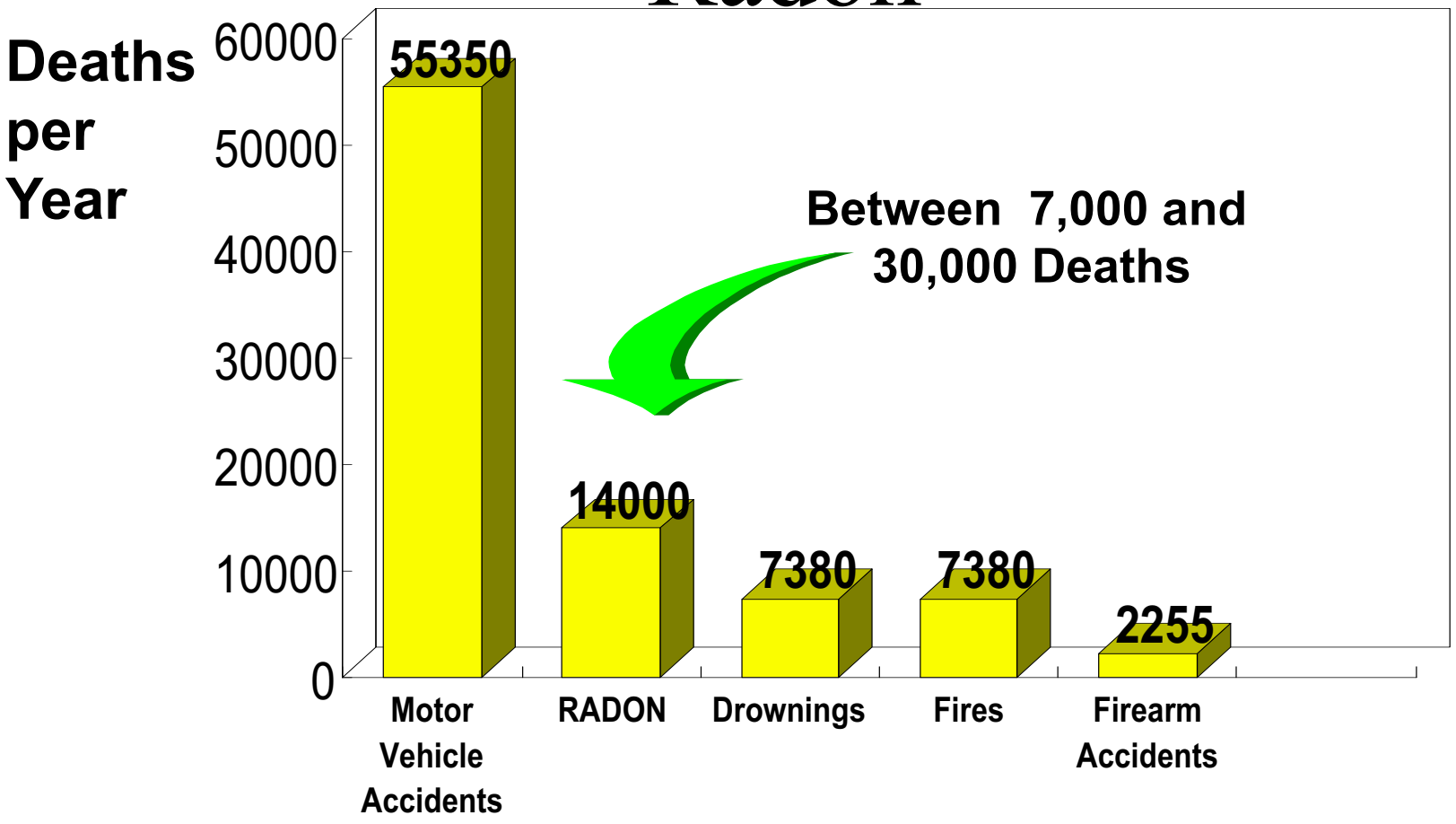
1. Cracks in Solid Floors
2. Construction Joints
3. Cracks in Walls
4. Gaps in Floors
5. Gaps around Pipes
6. Cavities in Walls
7. The Water Supply



How is Radon Detected

- **Charcoal Canisters**
- **Alpha Track Detectors**
- **Electret Monitors**
- **Radon Sniffers**

Cancer Death Estimates for Radon



Radon Risk If You Smoke...

Radon Level	If 1,000 people who smoked were exposed to this level over their lifetime..	The risk of cancer exposure compares to..
20 pCi/l	About 135 people could get lung cancer	←100 times the risk of drowning
10 pCi/l	About 71 people could get lung cancer	←100 times the risk of dying in a home fire
8 pCi/l	About 57 people could get lung cancer	
4 pCi/l	About 29 people could get lung cancer	←100 times the risk of dying in an air plane crash
2 pCi/l	About 15 people could get lung cancer	←2 times the risk of dying in a car crash
1.3 pCi/l	About 9 people could get lung cancer	(Average indoor radon level)
0.4 pCi/l	About 3 people could get lung cancer	(Average outdoor radon level)

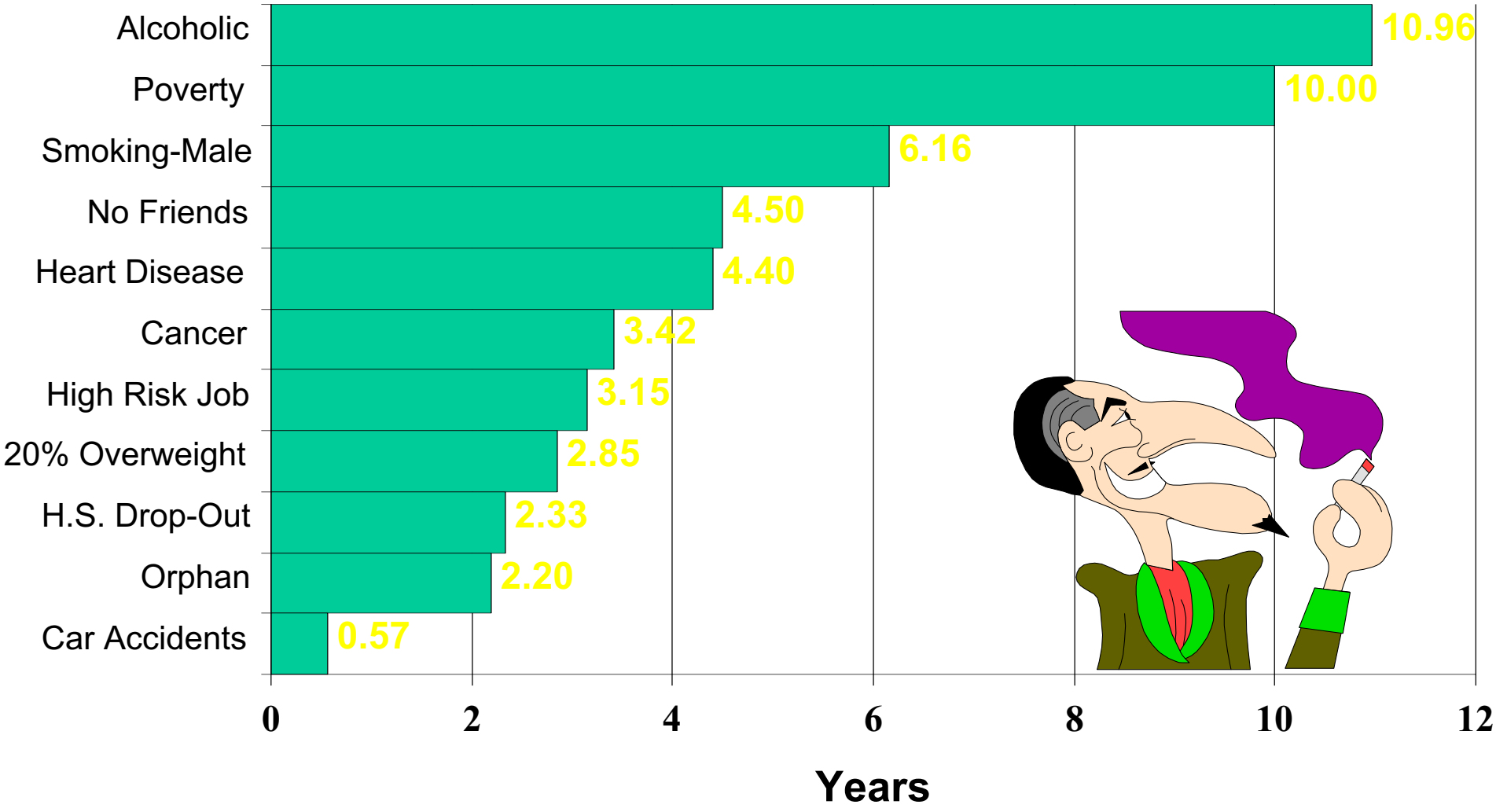
Radon Risk If You've Never Smoked

Radon Level	If 1,000 people who smoked were exposed to this level over their lifetime..	The risk of cancer exposure compares to..
20 pCi/l	About 8 people could get lung cancer	←Risk of being killed in a violent crime
10 pCi/l	About 4 people could get lung cancer	
8 pCi/l	About 3 people could get lung cancer	←10 times the risk of dying an an airplane crash
4 pCi/l	About 2 people could get lung cancer	←The risk of drowning
2 pCi/l	About 1 person could get lung cancer	←The risk of dying in a home fire
1.3 pCi/l	Less than 1person could get lung cancer	(Average indoor radon level)
0.4 pCi/l	Less than 1 person could get lung cancer	(Average outdoor radon level)

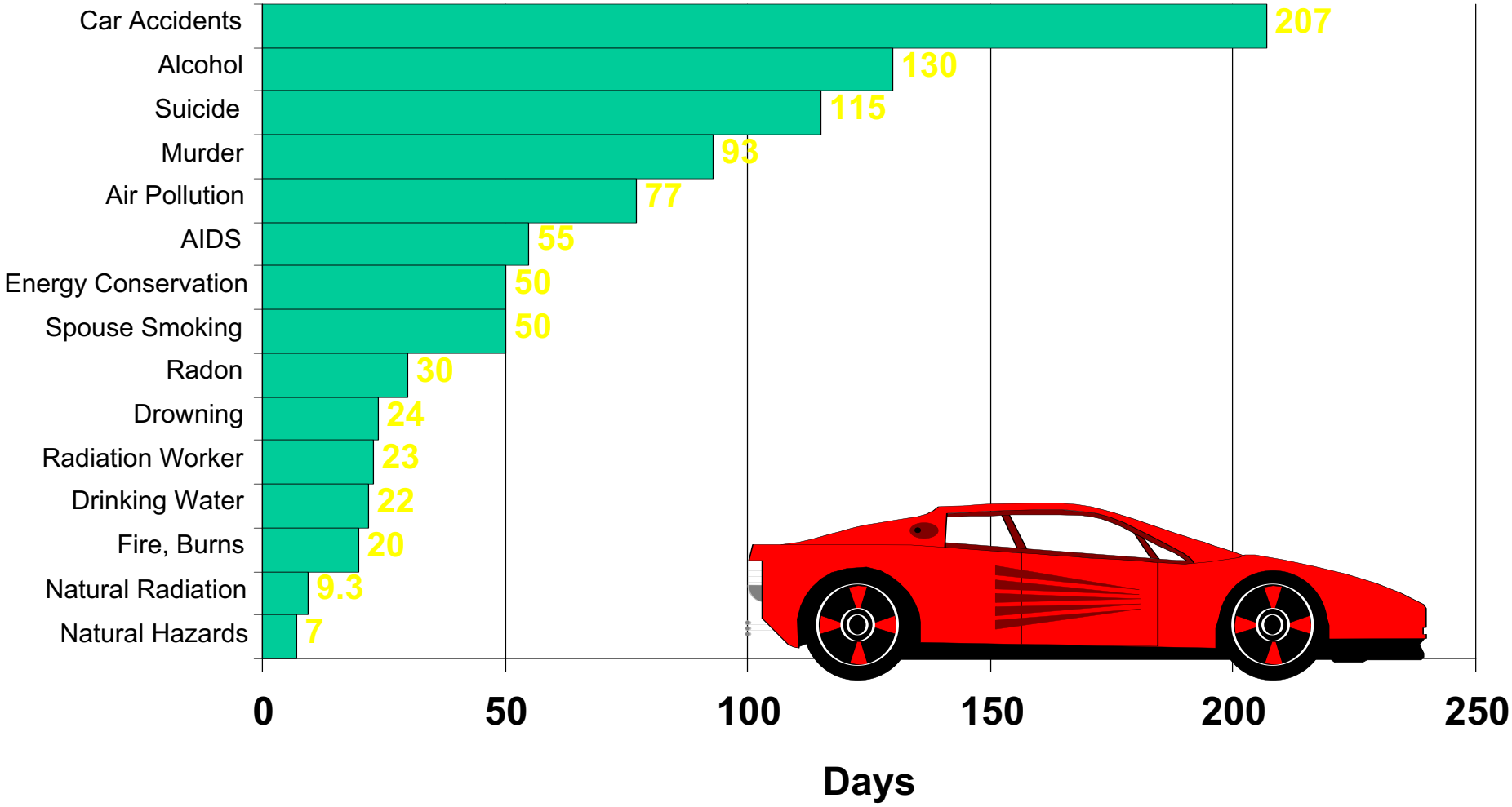
Radiation and Risk

How Risky is it Really??

Years from Your Life



Days from Your Life



Hours from Your Life