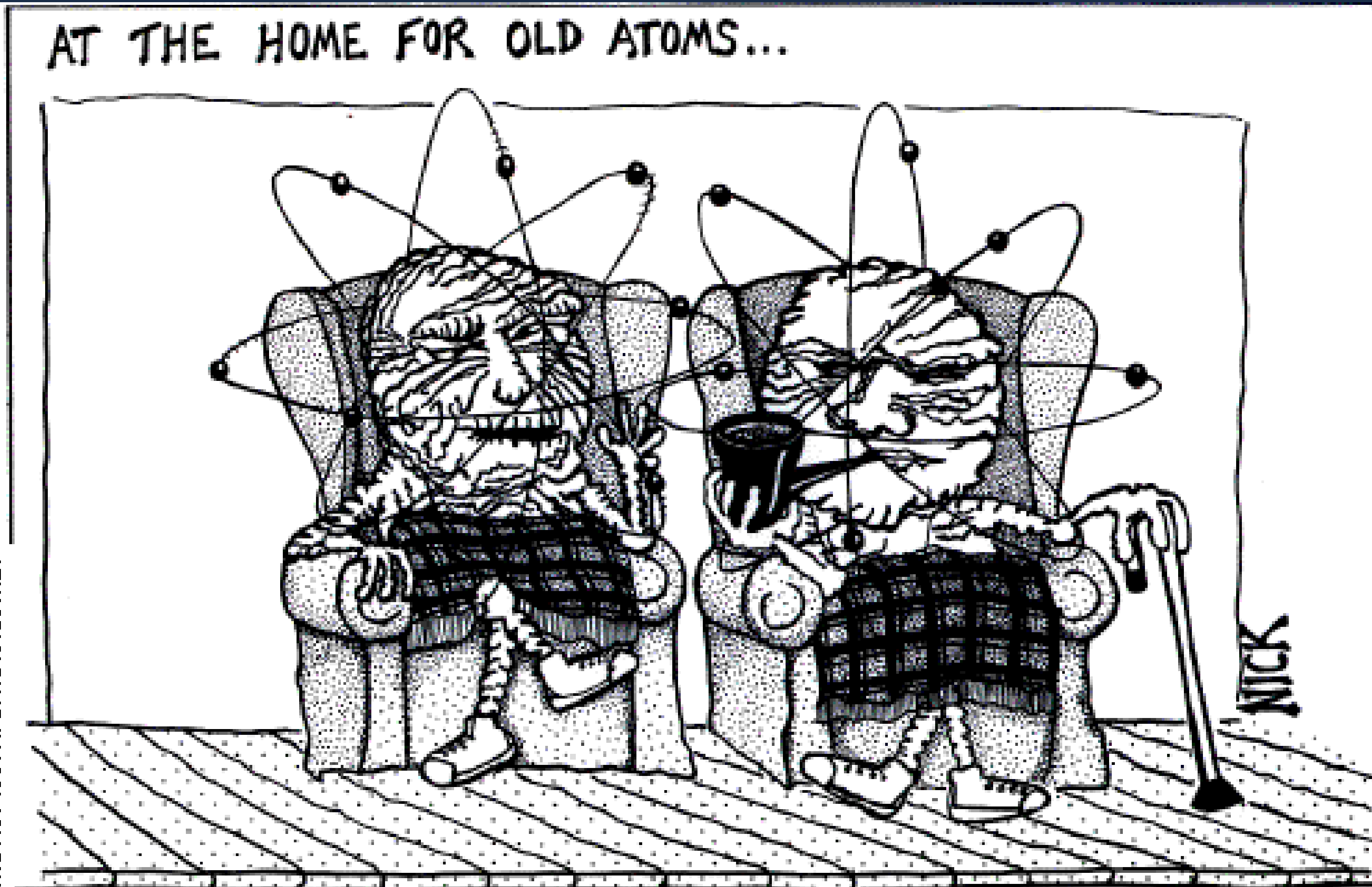
Welcome To RadTown USA

- Click to Explore RadTown USA

- Click on any location in RadTown USA and find out about radiation sources or uses at that location.



"When I was young I used to feel so alive, so dangerous..! In fact, would you believe that I started out life as a Uranium-238 ? Then one day I accidentally ejected an alpha particle, and that's where it all began. Now look at me, a spent old atom of Lead-206. It seems that all my life since then has been nothing but decay, decay, decay...."

The Alpha, Beta, Gammas of Nuclear Education
March 2nd, 2014

Fundamentals of Ionizing Radiation

Debra N Thrall, PhD
Executive Director
Albert I Pierce Foundation

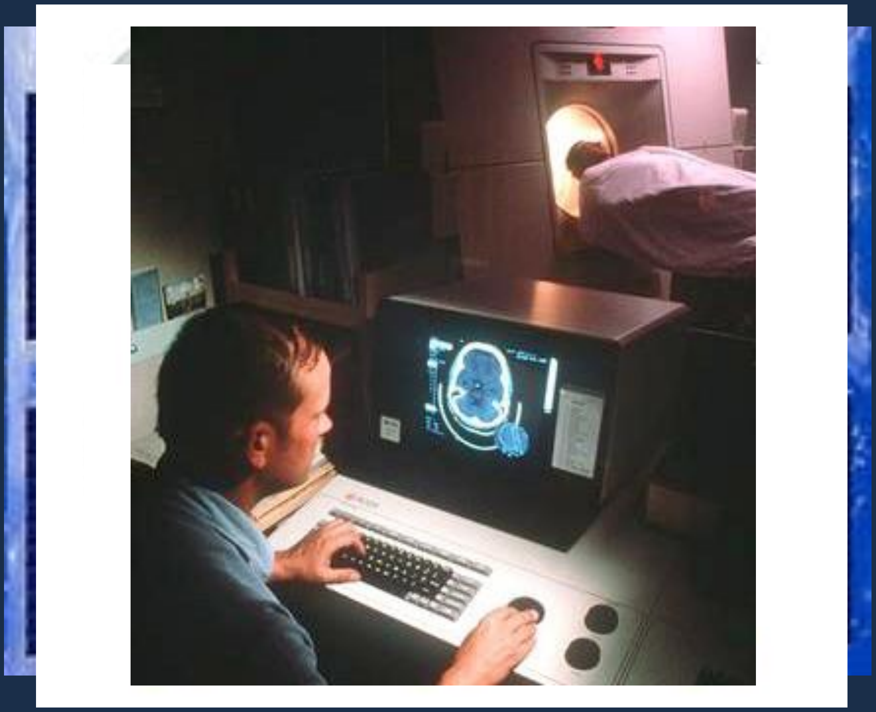
Radiation Fundamentals

- What is radiation?
- Where does it come from?
- How does it interact with matter?
- What is radioactivity?
- What are fission and fusion?
- How are radiation and radioactivity quantified?

Do you think of these “people” when I say RADIATION?

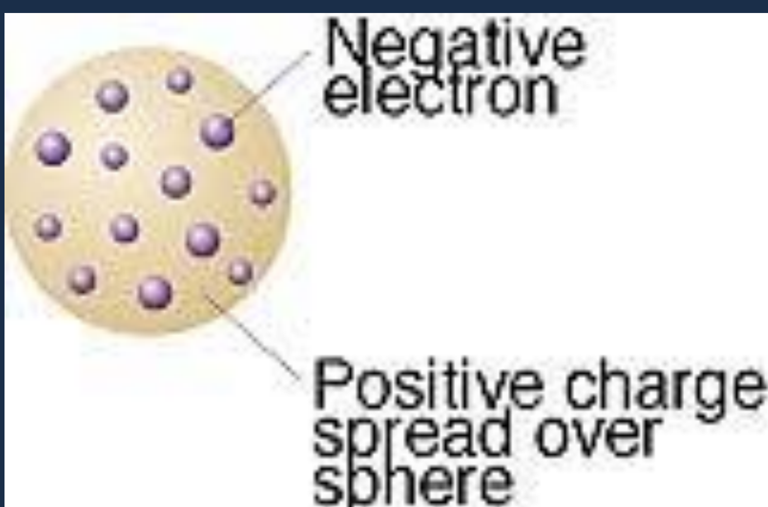
Do you think of these things as well?

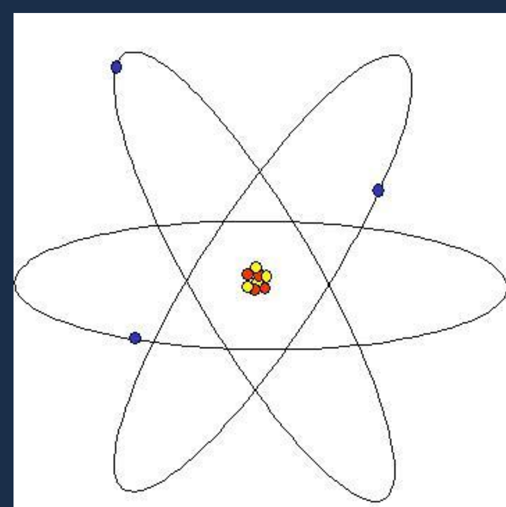
- Food
- Space
- Utilities
- Consumer Products
- Medicine

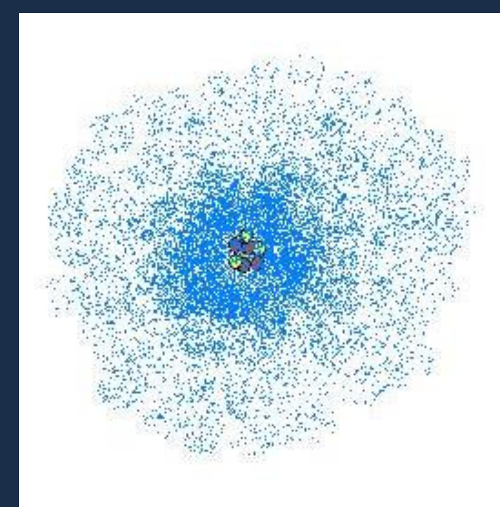


Brief History of the Atom

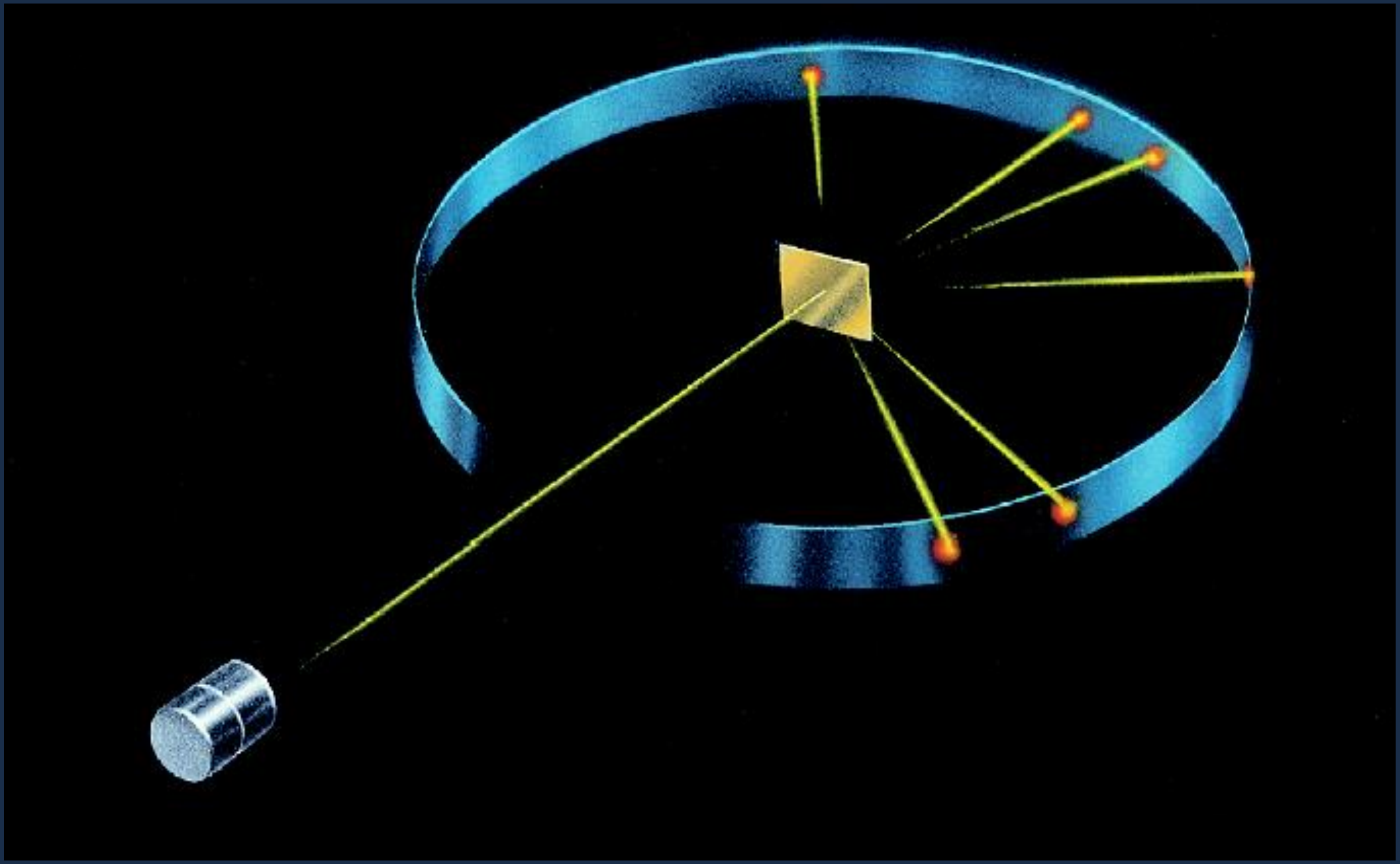
- 500 BC Democritus Atom
- Long time (Romans → Dark Ages)
- 1808 AD Dalton Plum Pudding
- 1911 Rutherford Nucleus
- 1913 Bohr Orbits
- 1920's Many People Quantum Mechanics







Rutherford’s Gold Foil Experiment

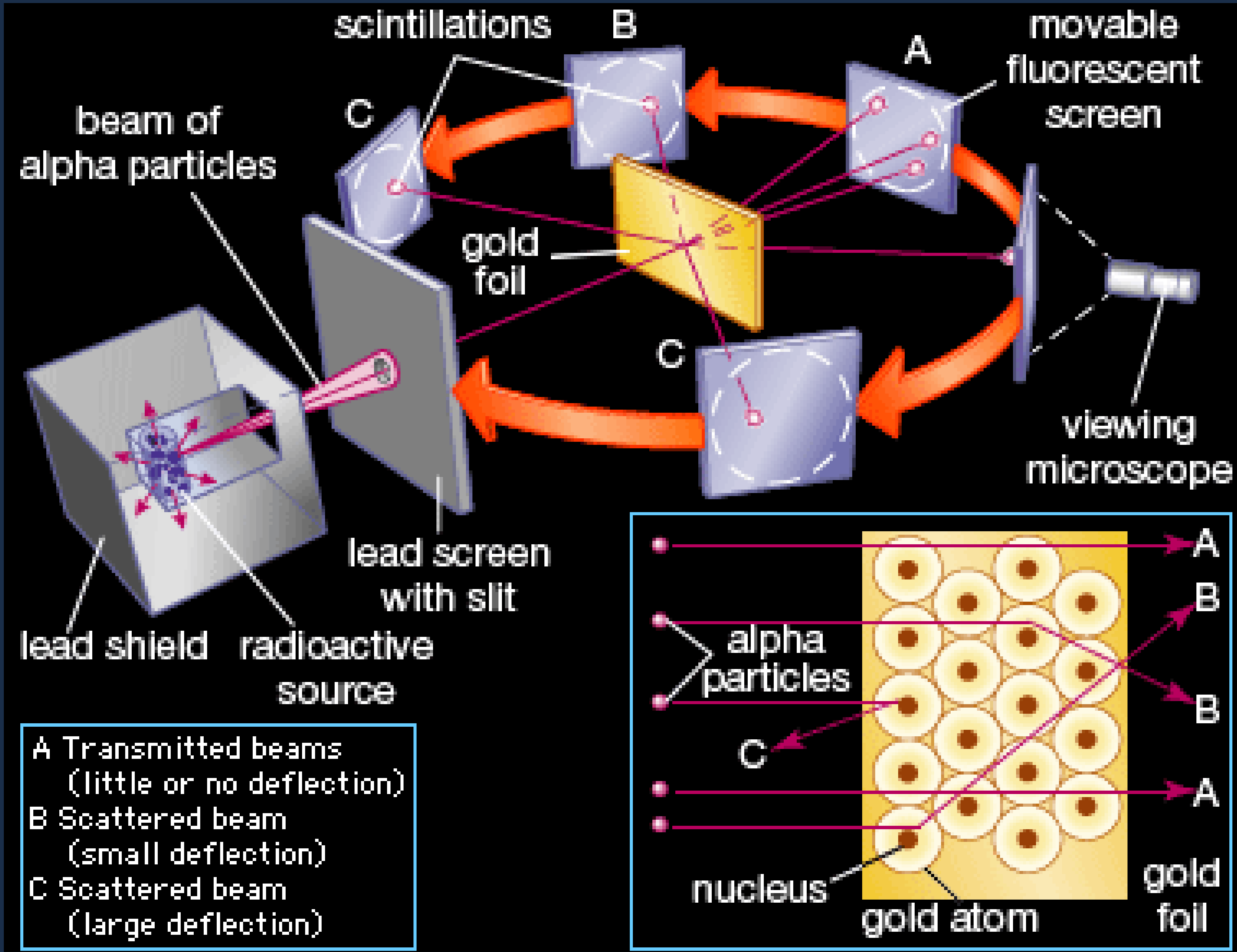


The Design

1. Bombard positively charged alpha particles into thin gold foil.

2. Use fluorescent screen to detect particles as they exit the gold foil.

3. Use angle of deflection to determine interior of the atom.


scintillations
B
A
movable fluorescent screen
C
beam of alpha particles
gold foil
C
viewing microscope
lead screen with slit
lead shield
radioactive source
A Transmitted beams (little or no deflection)
B Scattered beam (small deflection)
C Scattered beam (large deflection)
A
B
alpha particles
B
C
A
nucleus
gold atom
gold foil

So, What is an Atom?

- Atoms are made up of protons, neutrons & electrons

  - Protons: + charge p^+
  - Neutrons: no charge n^0
  - Electrons: - charge e^-

- Atoms want to have a stable energy level
  - This translates to having no net charge
  - # protons = # electrons

Mass of an Atom

- Masses
  - Proton: 1.000000 amu
  - Neutron: 1.000000 amu
  - Electron: 0.000549 amu

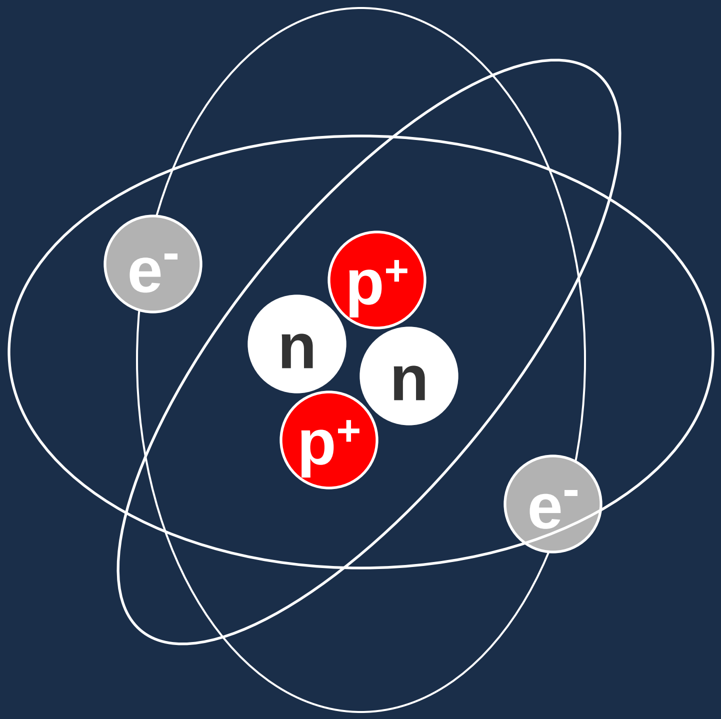
  (Translates to 1.2 lbs/1 ton ~ a kitten on an elephant!)

- The mass of an atom is approximately due to the mass of the protons and neutrons

- Mass atom = number p^+ + number n^0

Atomic Structure of Helium

THE HELIUM ATOM



HELIUM'S SUBATOMIC COMPOSITION

- 2 Protons
- 2 Neutrons
- 2 Electrons

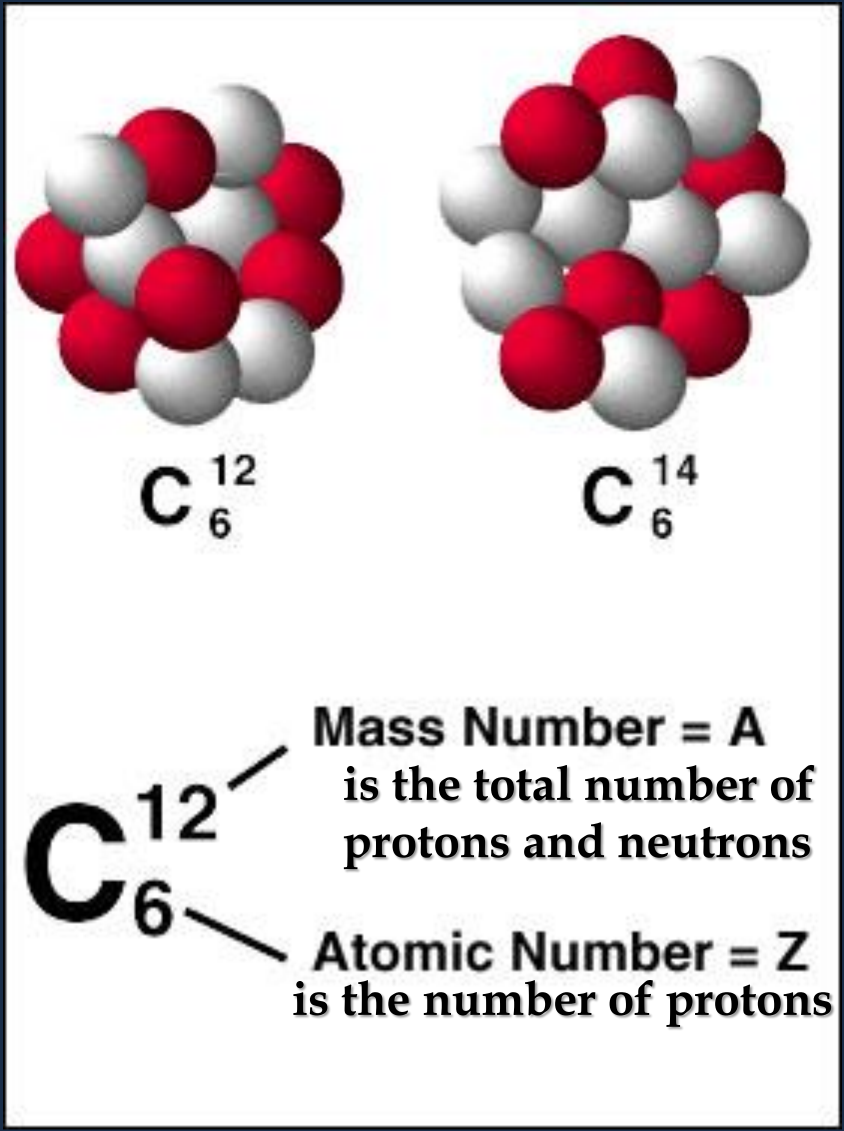
Isotopes – Defined

- Isotopes are elements with different amounts of neutrons
- The number of protons is identical
- They have similar properties
- There are stable and unstable versions of atoms
- They are naturally occurring & man made

Examples of Isotopes

- H-1 Hydrogen 1 proton 0 neutron
- H-2 Deuterium 1 proton 1 neutron
  - *Heavy hydrogen*
- H-3 Tritium 1 proton 2 neutrons

More on atomic structure . . .



p^+

Protons have a large mass and a positive charge. The number of protons identifies an element.

n

Neutrons have a large mass approximately equal to a proton's mass. Neutrons have no charge.

e^-

Electrons have a very small mass and a negative charge. Electrons travel outside the nucleus.

Periodic Table of the Elements

Solids
Liquids
Gases
Artificially Prepared

Atomic Number	Symbol	Name	Atomic Weight
26	Fe	Hydrogen	1.0079

PERIOD \ GROUP	IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA			IB	IIB	IIIB	IVB	VB	VIB	VIIB	VIII
1	1 **H** Hydrogen 1.00794																	2 **He** Helium 4.00260
2	3 **Li** Lithium 6.941	4 **Be** Beryllium 9.01218											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.99840	10 **Ne** Neon 20.1797
3	11 **Na** Sodium 22.98977	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.98154	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.97376	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
4	19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.95591	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.93805	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.93320	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
5	37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
6	55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327		72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
7	87 **Fr** Francium (223)	88 **Ra** Radium (226)		104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (268)	110 **Uun** Ununnilium (269)	111 **Uuu** Unununium (272)	112 **Uub** Ununbium						

57 **La** Lanthanum 138.9055	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
89 **Ac** Actinium (227)	90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Predict Radioactivity of an Isotope

Stable Isotopes have a specific ratio of neutrons to protons.

Unstable Isotopes which are radioactive fall outside the 'stable zone' of neutron to proton ratios.

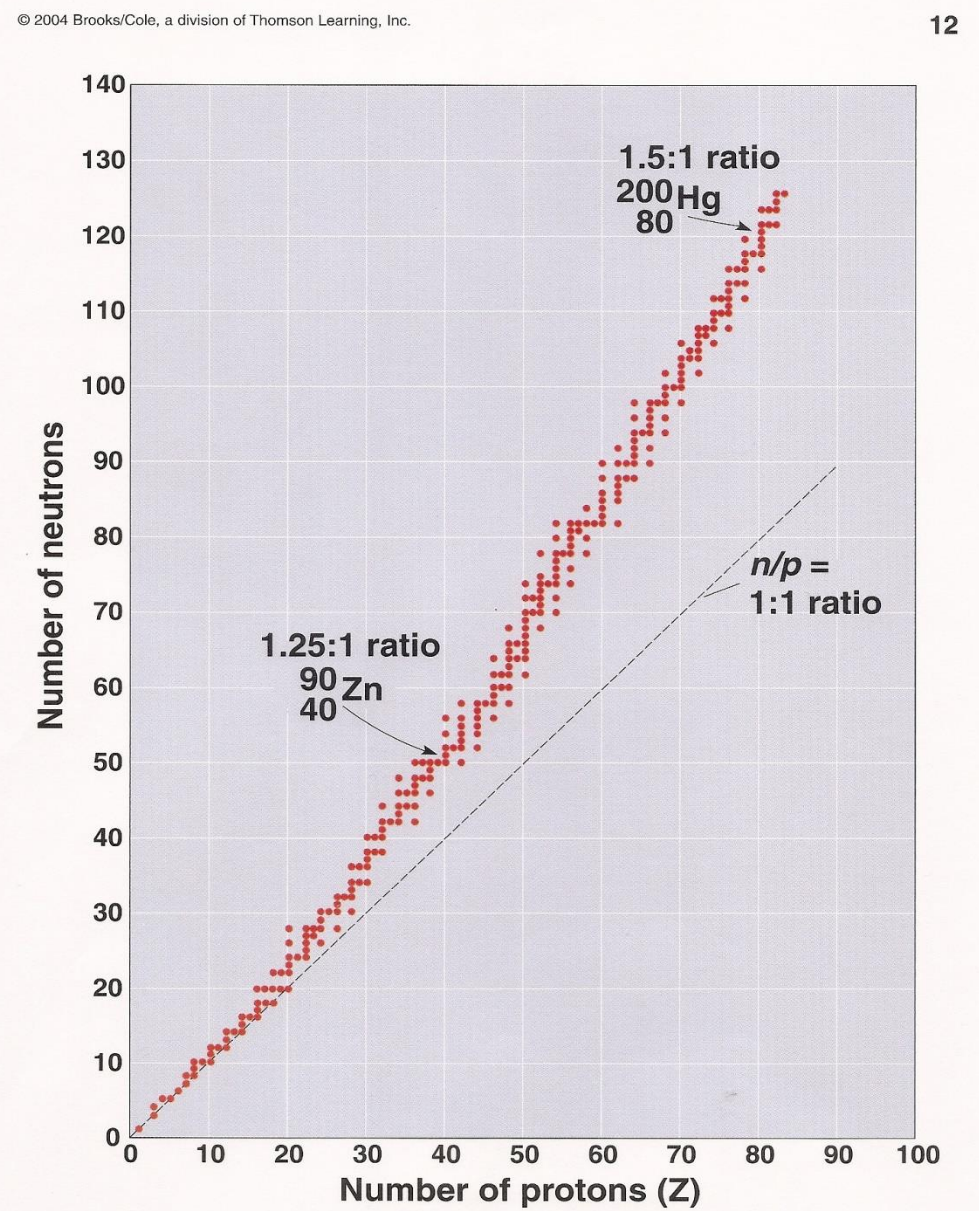
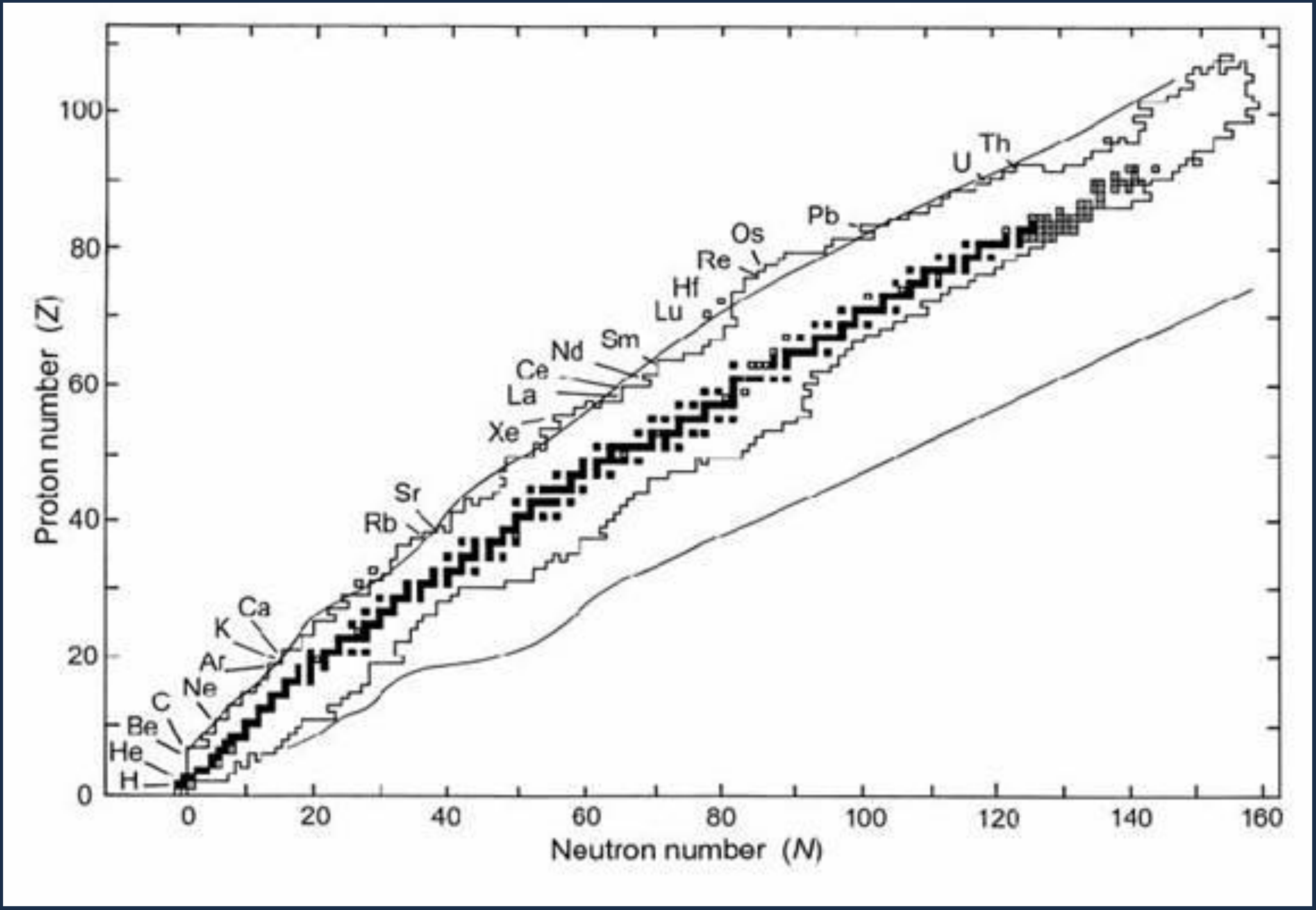


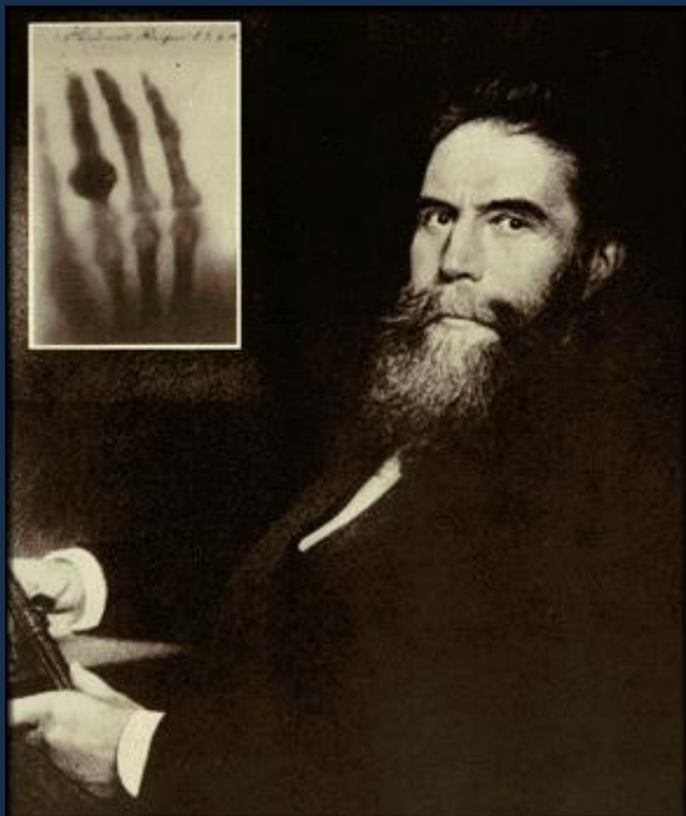
Figure 2.5 Neutron-to-proton ratios of stable isotopes.

Chart of the Nuclides

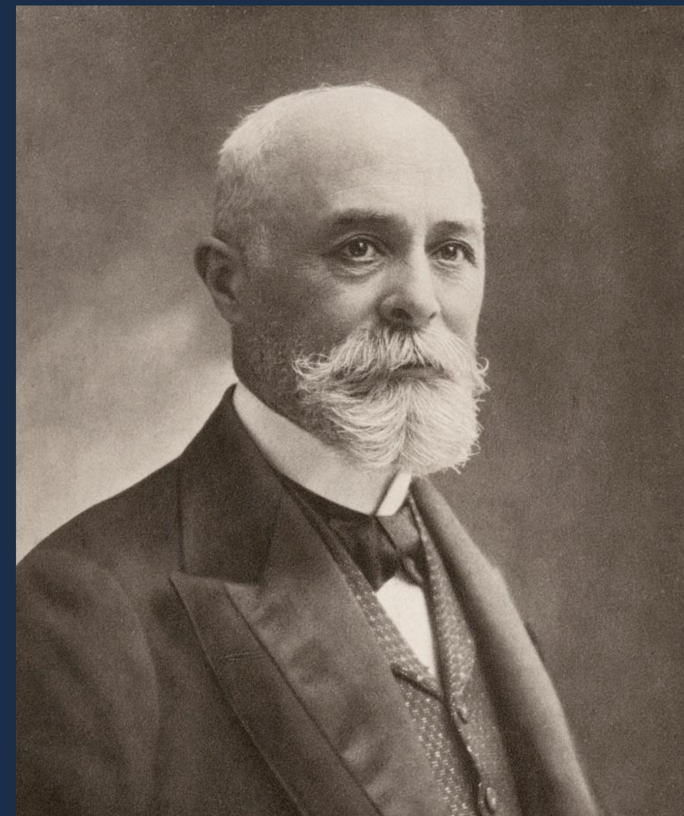


17												Cl28	Cl29 <20 NS	Cl30 <30 NS	Cl31 150 MS	Cl32 298 MS	Cl33 2.511 S	Cl34 1.5264 S	Cl35 75.77	Cl36 301000 Y	Cl37 24.23	Cl38 37.24 M
16											S26 ~10 MS	S27 21 MS	S28 125 MS	S29 187 MS	S30 1.178 S	S31 2.572 S	S32 95.02	S33 0.75	S34 4.21	S35 87.38 D	S36 0.02	S37 5.05 M
15										P24	P25 <30 NS	P26 20 MS	P27 260 MS	P28 270.3 MS	P29 4.142 S	P30 2.498 M	P31 100	P32 14.262 D	P33 25.34 D	P34 12.43 S	P35 47.3 S	P36 5.6 S
14									Si22 29 MS	Si23 >200 NS	Si24 102 MS	Si25 220 MS	Si26 2.234 S	Si27 4.16 S	Si28 92.230	Si29 4.683	Si30 3.087	Si31 157.3 M	Si32 172 Y	Si33 6.332 S	Si34 2.77 S	Si35 0.78 S
13									Al21 <35 NS	Al22 59 MS	Al23 0.47 S	Al24 2.053 S	Al25 7.183 S	Al26 717000 Y	Al27 100	Al28 2.2414 M	Al29 6.56 M	Al30 3.60 S	Al31 644 MS	Al32 33 MS	Al33 >1 US	Al34 60 MS
12								Mg19	Mg20 90.8 MS	Mg21 122 MS	Mg22 3.857 S	Mg23 11.317 S	Mg24 78.99	Mg25 10.00	Mg26 11.01	Mg27 9.458 M	Mg28 20.915 H	Mg29 1.30 S	Mg30 335 MS	Mg31 230 MS	Mg32 120 MS	Mg33 90 MS
11							Na17	Na18	Na19 <40 NS	Na20 447.9 MS	Na21 22.49 S	Na22 2.6019 Y	Na23 100	Na24 14.9512 H	Na25 59.1 S	Na26 1.072 S	Na27 301 MS	Na28 30.5 MS	Na29 44.9 MS	Na30 48 MS	Na31 17.0 MS	Na32 13.2 MS
10						Ne15		Ne17 109.2 MS	Ne18 1672 MS	Ne19 17.22 S	Ne20 90.48	Ne21 0.27	Ne22 9.25	Ne23 37.24 S	Ne24 3.38 M	Ne25 602 MS	Ne26 0.197 S	Ne27 32 MS	Ne28 17 MS	Ne29 200 MS	Ne30 >200 NS	Ne31 >260 NS
9						F14			F17 64.49 S	F18 109.77 M	F19 100	F20 11.163 S	F21 4.158 S	F22 4.23 S	F23 2.23 S	F24 0.34 S	F25 59 MS	F26 190 MS	F27 >200 NS	F28 <40 NS	F29 >200 NS	
8						O13 8.58 MS	O14 70.606 S	O15 122.24 S	O16 99.762	O17 0.038	O18 0.200	O19 26.91 S	O20 13.51 S	O21 3.42 S	O22 2.25 S	O23 82 MS	O24 61 MS	O25 <50 NS	O26 <40 NS			
7				N10		N12 11.000 MS	N13 9.965 M	N14 99.634	N15 0.366	N16 7.13 S	N17 4.173 S	N18 624 MS	N19 290 MS	N20 142 MS	N21 87 MS	N22 18 MS	N23 >200 NS	N24 <52 NS				
6				C9 126.5 MS	C10 19.255 S	C11 20.39 M	C12 98.89	C13 1.11	C14 5730 Y	C15 2.449 S	C16 0.747 S	C17 193 MS	C18 95 MS	C19 49 MS	C20 14 MS	C21 <30 NS	C22 >200 NS					
5				B8 770 MS		B10 19.8	B11 80.2	B12 20.20 MS	B13 17.36 MS	B14 12.3 MS	B15 9.87 MS	B16 <190 PS	B17 5.08 MS	B18 <26 NS	B19 >200 NS							
4		Be5		Be7 53.29 D		Be9 100	Be10 1510000 Y	Be11 13.81 S	Be12 21.3 MS		Be14 4.35 MS											
3				Li6 7.59	Li7 92.41	Li8 838 MS	Li9 178.3 MS		Li11 8.5 MS	Li12 <10 NS												
2		He3 0.000137	He4 99.999863		He6 806.7 MS		He8 119.0 MS															
1	H1 99.985	H2 0.015	H3 12.33 Y																			
0		N1 10.24 M																				

100 Years of Radiation Discovery



<u>Wilhelm Roentgen</u>
Discovered the X-ray
Nov. 8, 1895



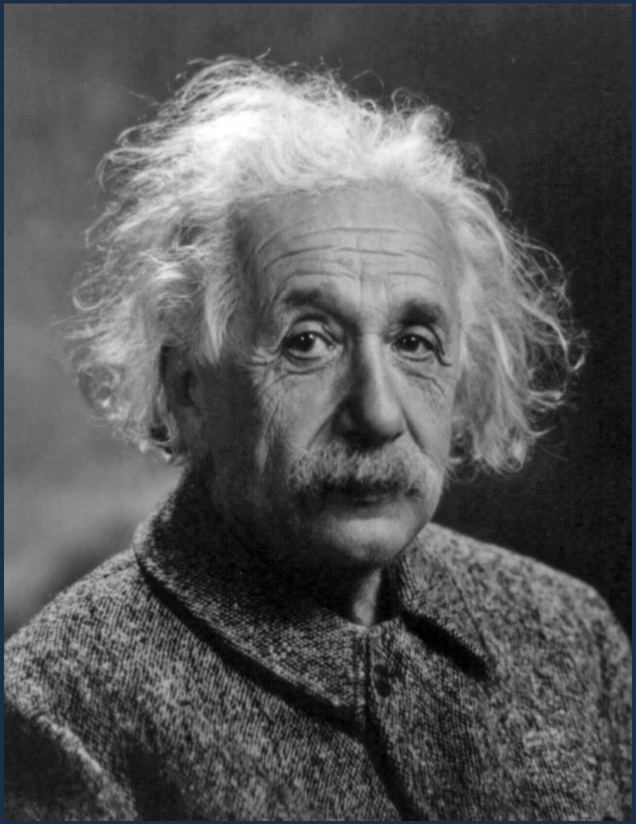
<u>Henri Becquerel</u>
Discovered radioactivity
1896

100 Years of Radiation Discovery

<u>Pierre & Marie Curie</u>
Discovered Radium
Coined the term, radioactivity

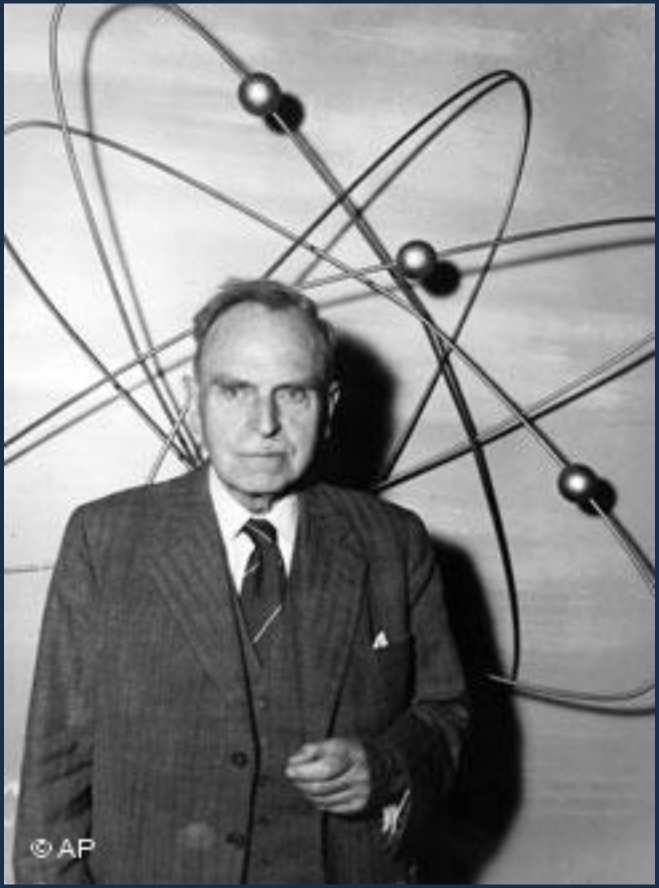
<u>Ernest Rutherford</u>
Father of Nuclear Physics
Named and Categorized:
Proton; Alpha, Beta Particle

100 Years of Radiation Discovery



<u>Albert Einstein</u>

Theory of Relativity led to new ideas about space, time, matter, energy, gravity

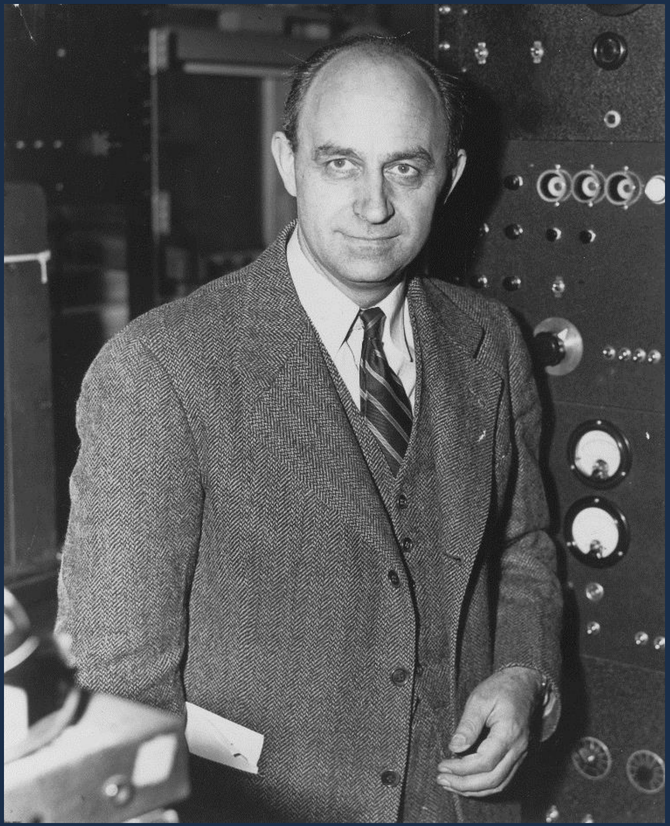


<u>Ernest Rutherford</u>

Discovered Nuclear Fission
1939

100 Years of Radiation Discovery

<u>Glenn Seaborg</u>
Discovered Plutonium
1941



<u>Enrico Fermi</u>
Produced the first man-made, self-sustaining nuclear chain reaction with his team on Dec. 2, 1942

NM and AZ have a long and diverse past with the nuclear industry.

They are almost synonymous with nuclear and the nuclear industry.

Nuclear research, mining and miling have changed the face of these states completely and irreversibly.

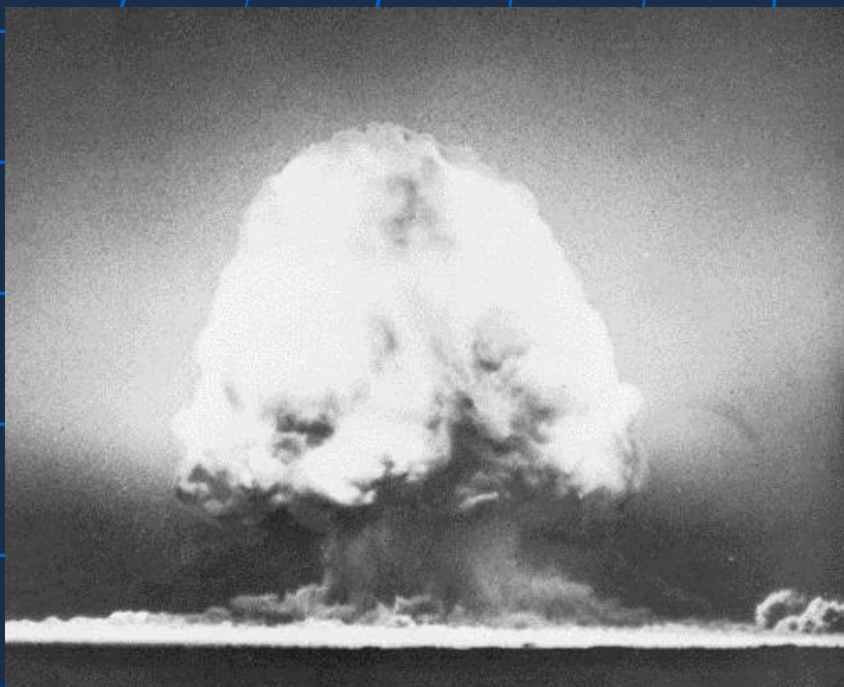
NM is considered to be the birthplace of the atomic bomb.

In 1943 - J. Robert Oppenheimer moved the Manhattan Project to Los Alamos, New Mexico which resulted in the creation of the Los Alamos National Laboratory

Why White Sands, New Mexico?

- “The critical requirement for a site for an atomic bomb design laboratory was enhanced security.
- Such a site needed to be safe from bombing by enemy aircraft and equally safe from curious citizens.”

Trinity Test Site
July 16th, 1945



Above: Bomb Detonation
Top Middle: “The Gadget”
Bottom Middle: Trinitite
Right: Bomb Drop Tower

August 1945

- Little Boy and Fat Man, dropped on Hiroshima and Nagasaki

- Sandia National Laboratories’ forerunner, known as Z Division on Sandia Base established as a site convenient to Los Alamos to continue weapon development.

Some members of the public seem to equate anything nuclear with the concept of nuclear weapons.

Mass Paranoia

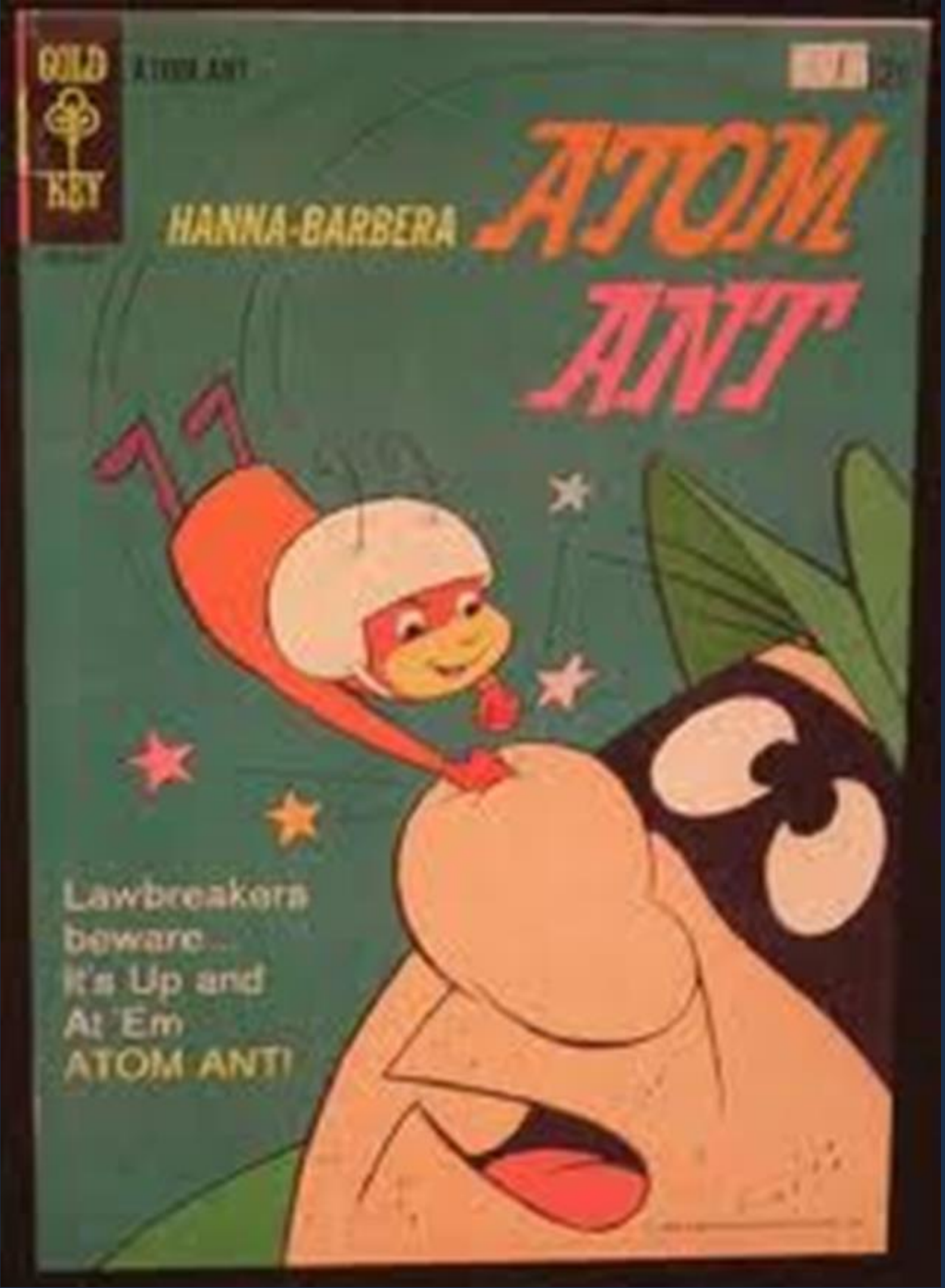
- Mass fear of Nuclear holocaust
- Fall out shelters constructed and bomb drills conducted – DUCK AND COVER!

RADIATION CINEMA! SCI-FI B-MOVIES & CLASSIC TV FROM THE ATOMIC AGE!

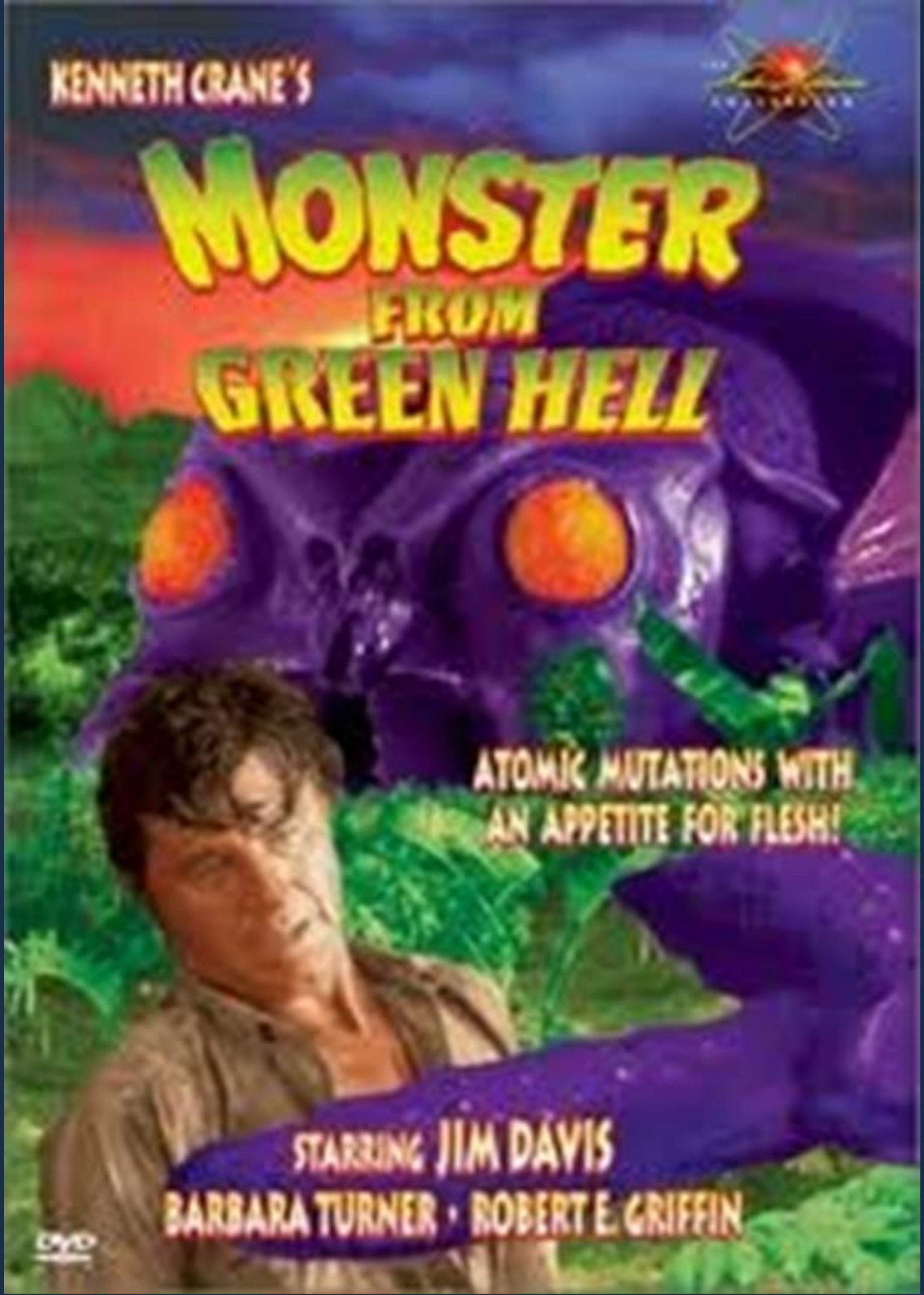
When Trinity was detonated it was the bang of a starting gun for B-movie makers everywhere!

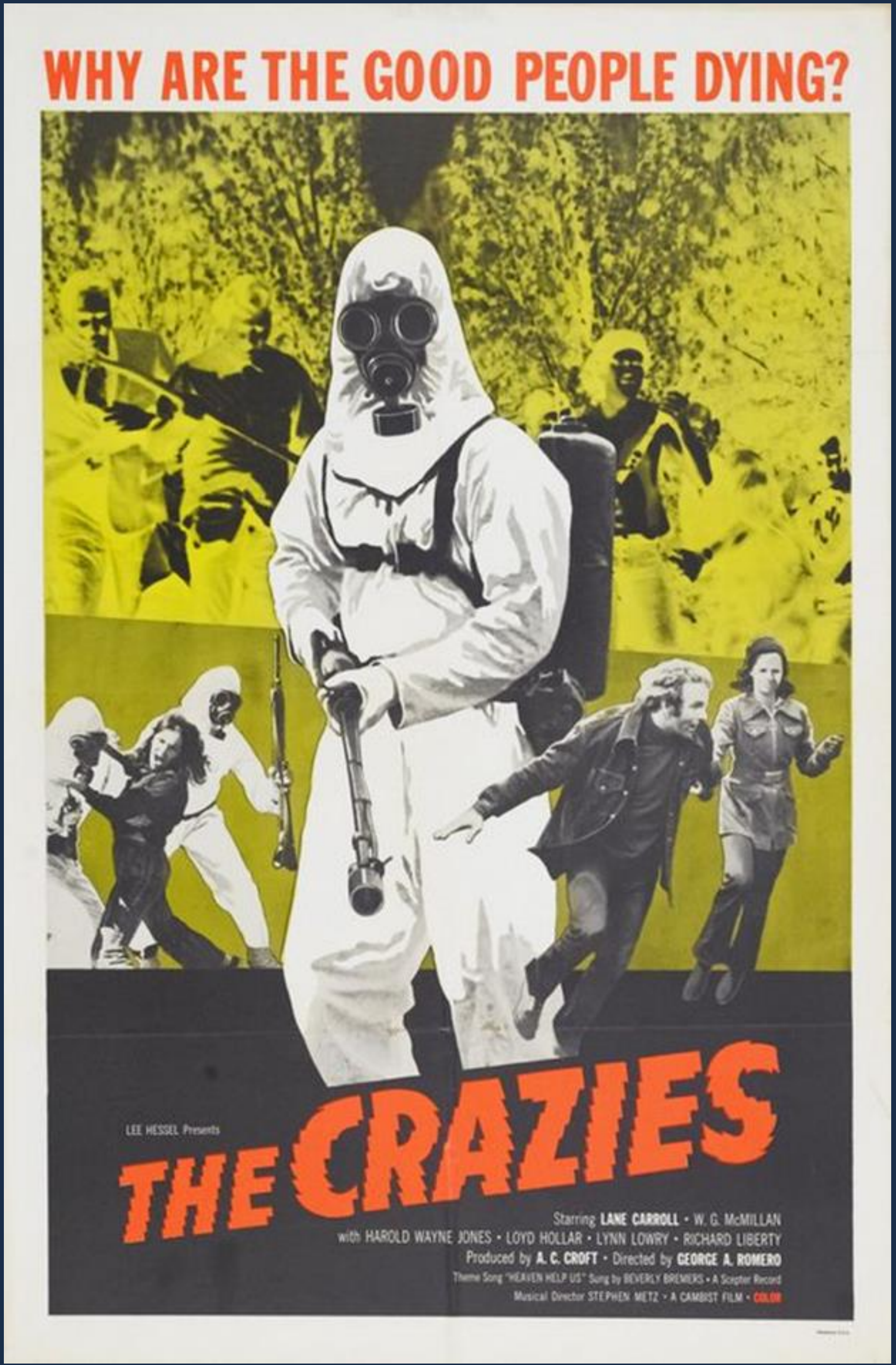
They saw visions of mutants, plagues, nuclear holocaust, empty cities covered in gray ash; and mushroom clouds rising like dollar signs on the screens of drive-ins everywhere.

DC
SUPERMAN
NATIONAL COMICS
ACTION COMICS
APPROVED BY THE COMICS CODE AUTHORITY
MAR.
NO. 361
12¢
I GAVE YOU TWO BLACK EYES, SUPERMAN... NOW I'M GOING TO BUST YOUR NOSE!
FEATURING:
"The POWER OF THE PARASITE!"


GOLD KEY
ATOM ANT
HANNA-BARBERA
ATOM ANT
Lawbreakers beware... It's Up and At 'Em ATOM ANT!


A HORROR HORDE OF CRAWL-AND-CRUSH GIANTS
CLAWING OUT OF THE EARTH
FROM MILE-DEEP
CATACOMBS!
"THEM"
"This city is under martial law until we annihilate THEM!"
Kill one and two take its place!
THE AMAZING NEW WARNER BROS. SENSATION!
"THEM!"
JAMES WHITMORE · EDMUND GWENN · JOAN WELDON · JAMES ARNESS


KENNETH CRANE'S
MONSTER FROM GREEN HELL
ATOMIC MUTATIONS WITH AN APPETITE FOR FLESH!
STARRING JIM DAVIS
BARBARA TURNER · ROBERT E. GRIFFIN
DVD


WHY ARE THE GOOD PEOPLE DYING?
LEE HESSEL Presents
THE CRAZIES
Starring LANE CARROLL • W. G. McMILLAN
with HAROLD WAYNE JONES • LOYD HOLLAR • LYNN LOWRY • RICHARD LIBERTY
Produced by A. C. CROFT • Directed by GEORGE A. ROMERO
Theme Song "HEAVEN HELP US" Sung by BEVERLY BREMERS • A Scepter Record
Musical Director STEPHEN METZ • A CAMBIST FILM • COLOR

PULL

COLD WAR HYSTERIA

8 26831 07041 4

DVD VIDEO




Relive the fear and paranoia of America's most dangerous era in one multi-disc Collectors Set.

Return to the era of nuclear brinkmanship and visceral fear that gripped the entire country with this amazing collection of documentaries and public service features. From atomic testing to fall-out shelters, canned and dried food caches and unintentionally comical safety advice for a nation of terrified Americans, the hysteria of a generation is captured here.

DISC 1

- Stay Safe, Stay Strong: The Facts About Nuclear Weapons
- About Fallout
- News Magazine of the Screen: The Atomic Energy
- Our Cities Must Fight
- Town of the Times
- Operation: Tumbler Snapper
- Operation: Greenhouse
- Operation: Plumbbob – Weapons Development Report
- Project Gnome
- Radiological Defense
- Atomic Proving Grounds – The Story of Operation: Sandstone
- Atomic Weapons Tests – Trinity Through Buster-Jangle
- Fallout: When and How to Protect Yourself

DISC 2

- Operation: Crossroads
- Operation: Ivy
- Management of Mass Casualties
- Special Delivery
- Tale of Two Cities
- Bombproof
- Information Program Within Public Shelters
- Occupying a Public Shelter
- Target: You!
- Warning Red
- Operation: Hardtack
- Medic: Flash of Darkness
- The Atom Strikes!

DISC 3

- This is Not a Test
- Red Chinese Battle Plan
- The Medical Aspects of Nuclear Radiation
- Operation: Cue
- The Atom and Biological Science
- Atomic Alert
- The Challenge of Ideas
- The House in the Middle
- Survival Under Atomic Attack
- What You Should Know About Biological Warfare
- A New Look at the H-Bomb
- Duck and Cover
- Let's Face It
- You Can Beat the A-Bomb
- A Day Called X
- Operation: Castle
- A is for Atom

Warning: Documentaries contain scenes that may be considered graphic and violent by some viewers.

Over 17 Hours of Color and B&W Documentary Footage   www.millcreekent.com

Where Does Radiation Come From?

Nuclear Decay - Radioactivity

Atomic Processes - X-rays

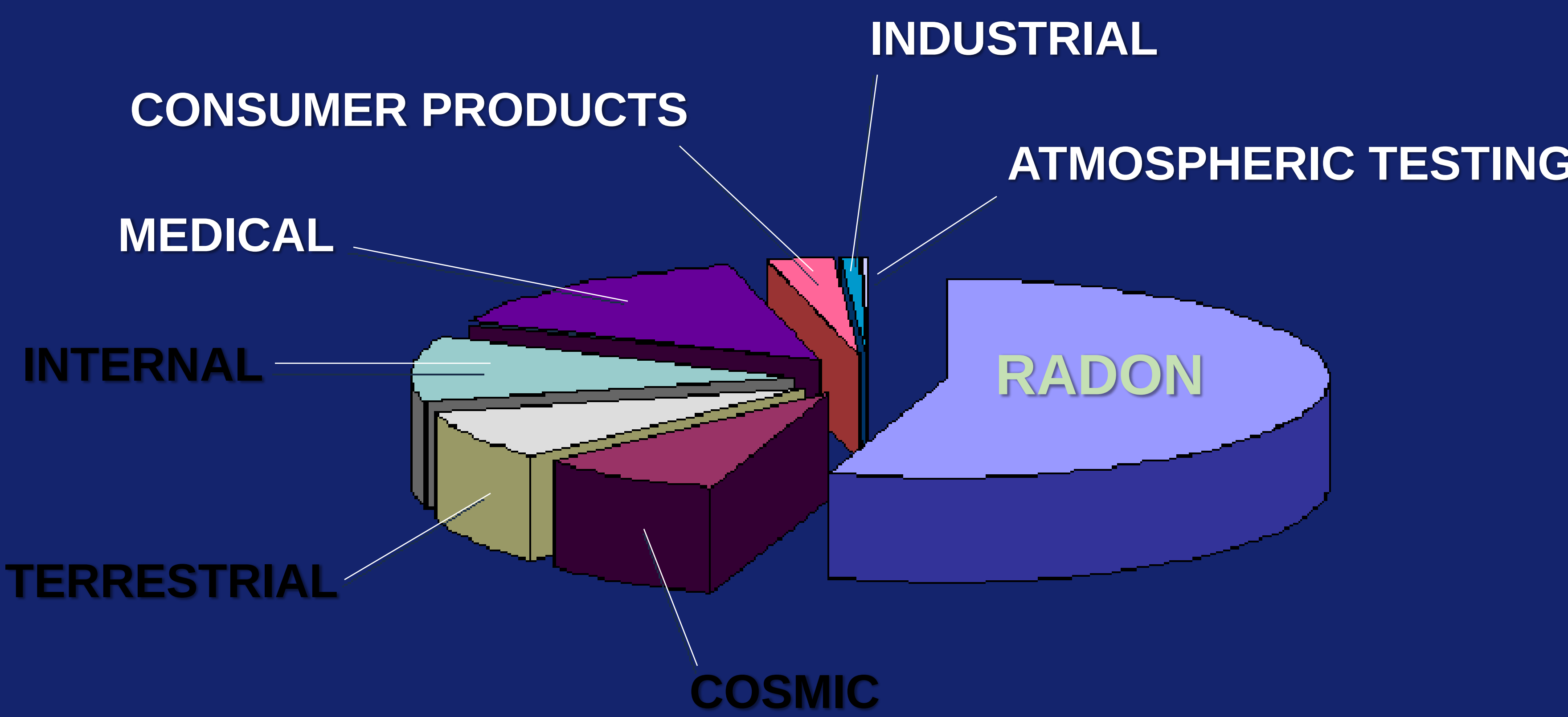
Nuclear Reactions

Fission

Fusion

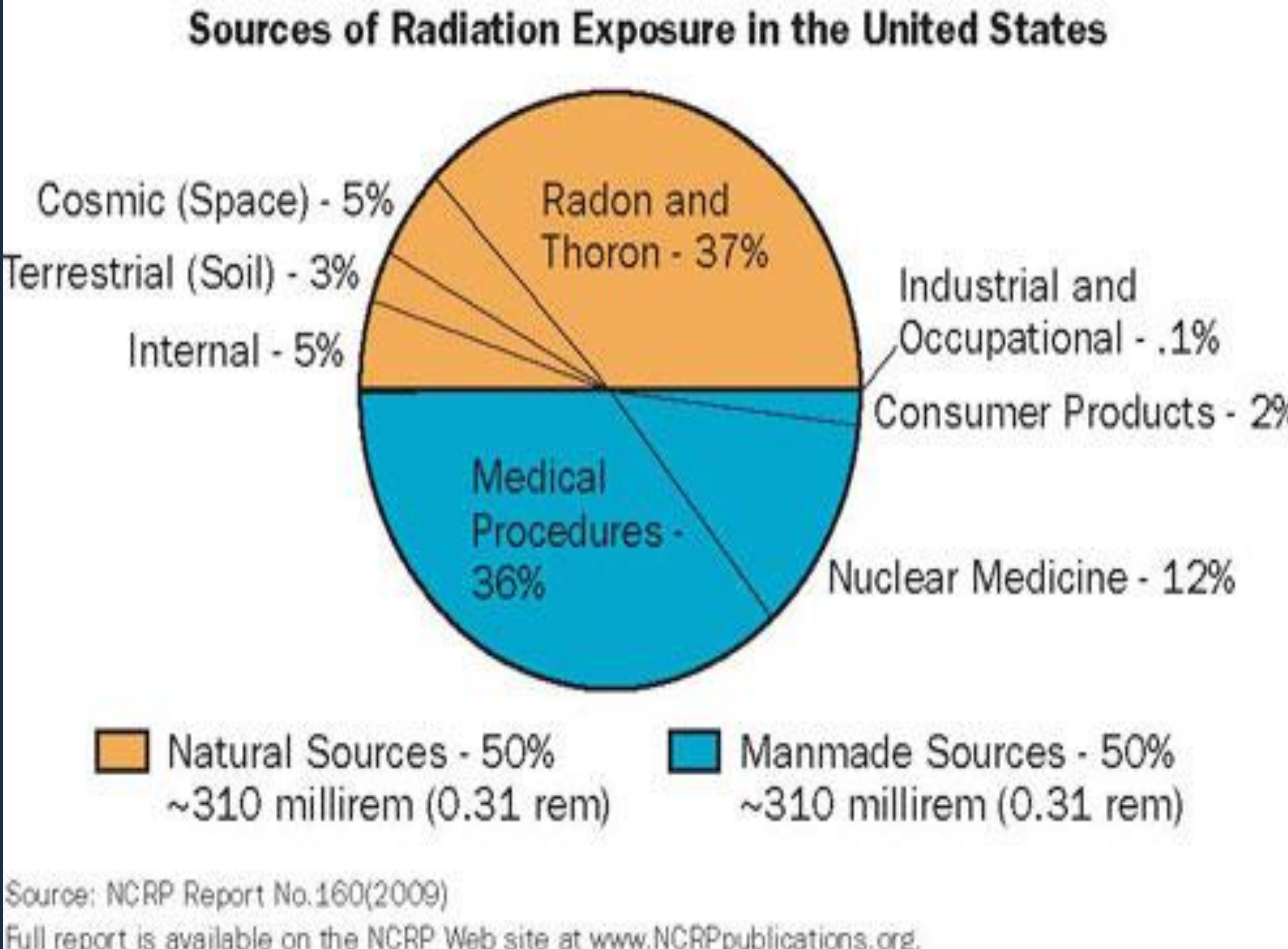
Others

Background Radiation Sources



NATURAL

MANMADE


Sources of Radiation Exposure in the United States
Cosmic (Space) - 5%
Terrestrial (Soil) - 3%
Internal - 5%
Radon and Thoron - 37%
Industrial and Occupational - .1%
Consumer Products - 2%
Medical Procedures - 36%
Nuclear Medicine - 12%
Natural Sources - 50% ~310 millirem (0.31 rem)
Manmade Sources - 50% ~310 millirem (0.31 rem)
Source: NCRP Report No.160(2009)
Full report is available on the NCRP Web site at www.NCRPpublications.org.

What is Radiation?

- ***Radiation = Energy in transit***

  …The transfer of energy by waves or particles

- ***Ionizing Radiation: Has sufficient energy to produce energetic ions in ordinary matter***

  …must result in the production of charged particles and eventual absorption of their kinetic energy

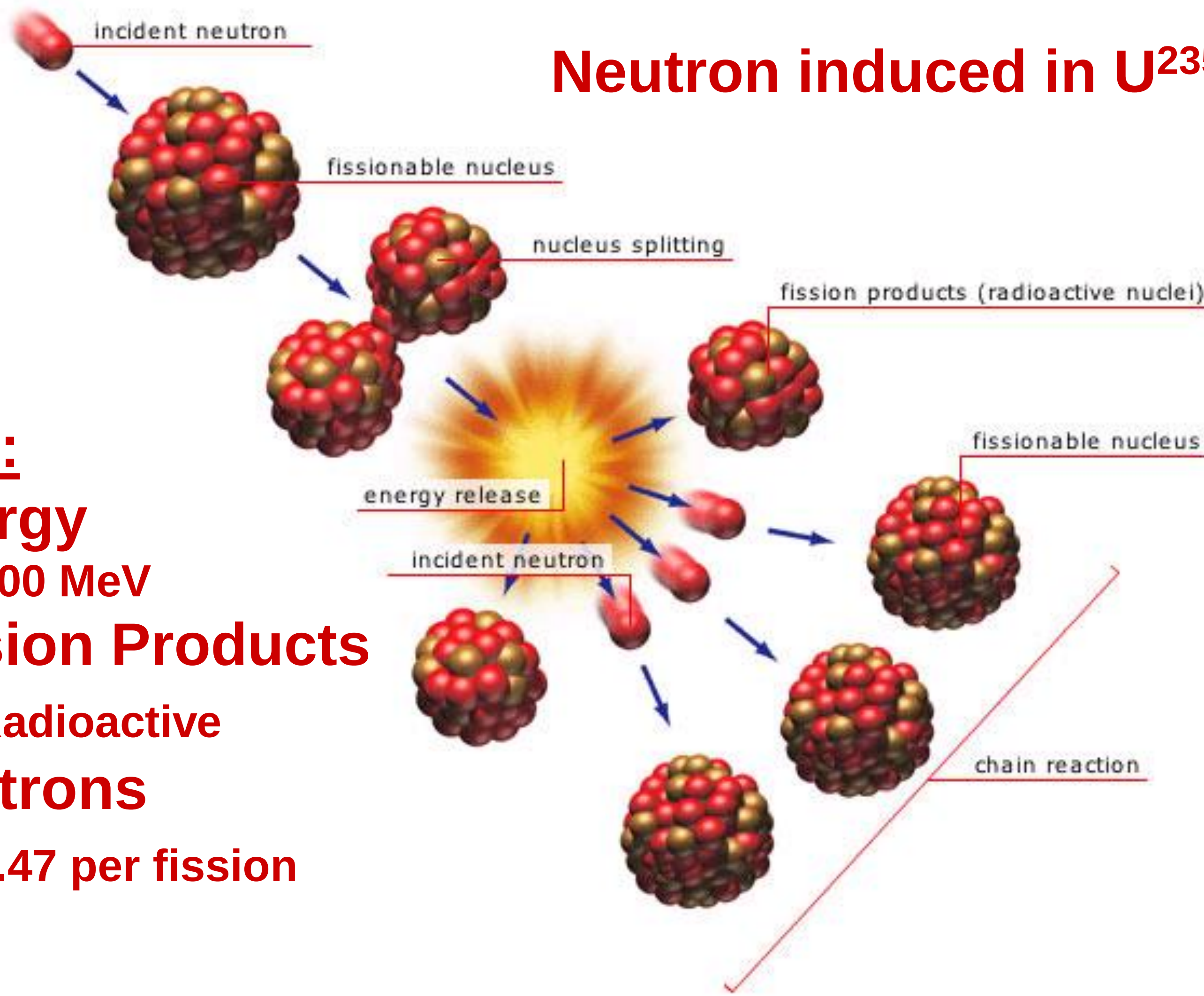
  Alpha and Beta particles, Gamma & X-rays, Neutrons

- ***Non-Ionizing Radiation: Does not produce energetic ions***

  Radio, Microwaves, UV, IR, Visible

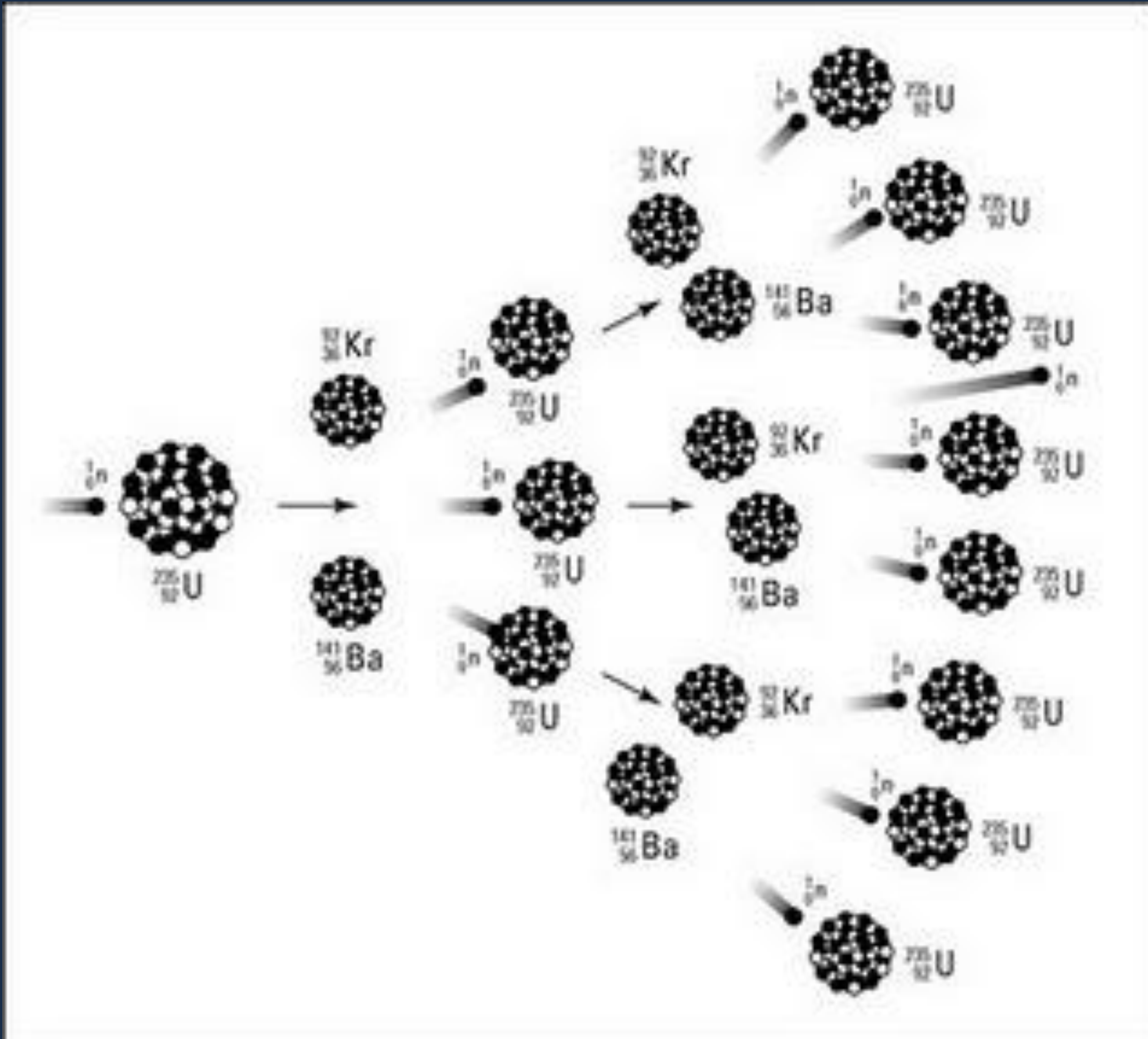
Nuclear Reactions - Fission

Neutron induced in U^{235}



Products:

- **Energy**
  - ~ 200 MeV
- **Fission Products**
  - Radioactive
- **Neutrons**
  - 2.47 per fission

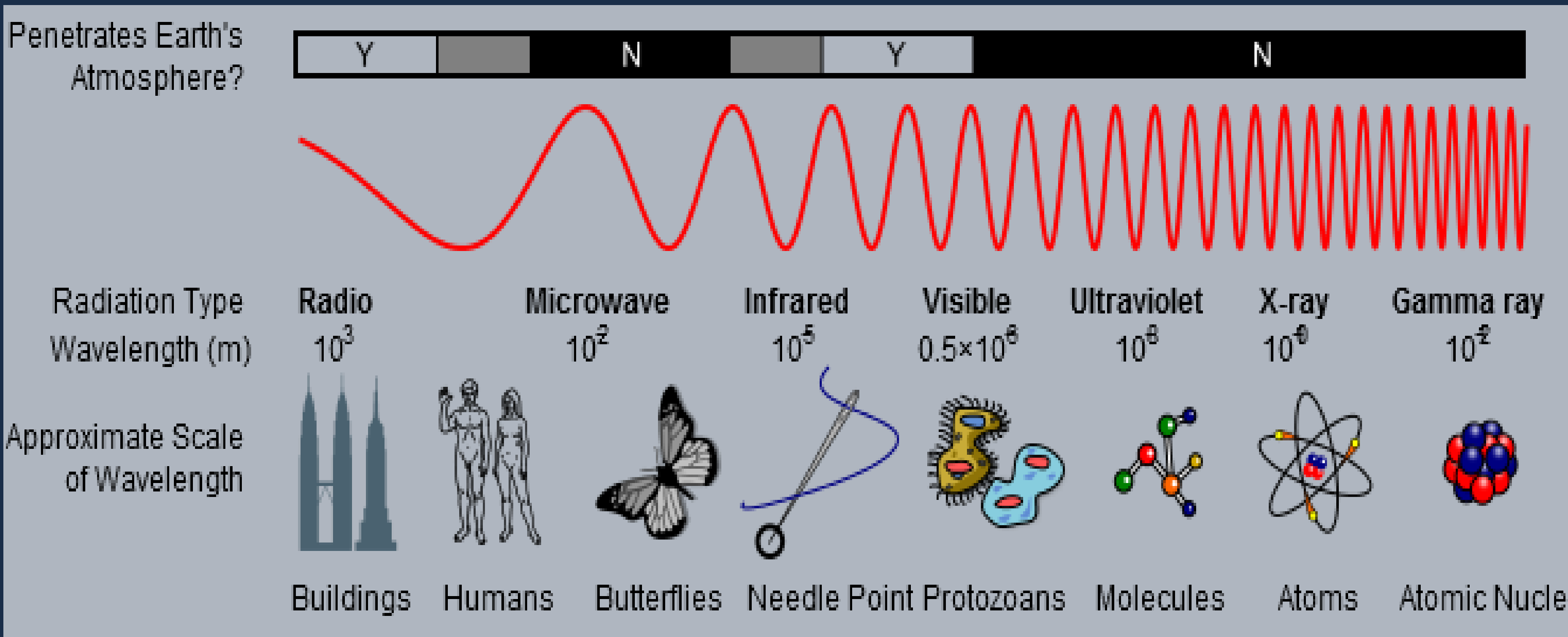


$^{1}_{0}n$
$^{235}_{92}U$
$^{92}_{36}Kr$
$^{141}_{56}Ba$

Types of Radiation

Non-Ionizing	Ionizing
Radiowaves	*Alpha*
Microwaves	*Beta*
Infrared	*Gamma*
Ultraviolet	*X-Rays*
Visible Light	*Neutrons*

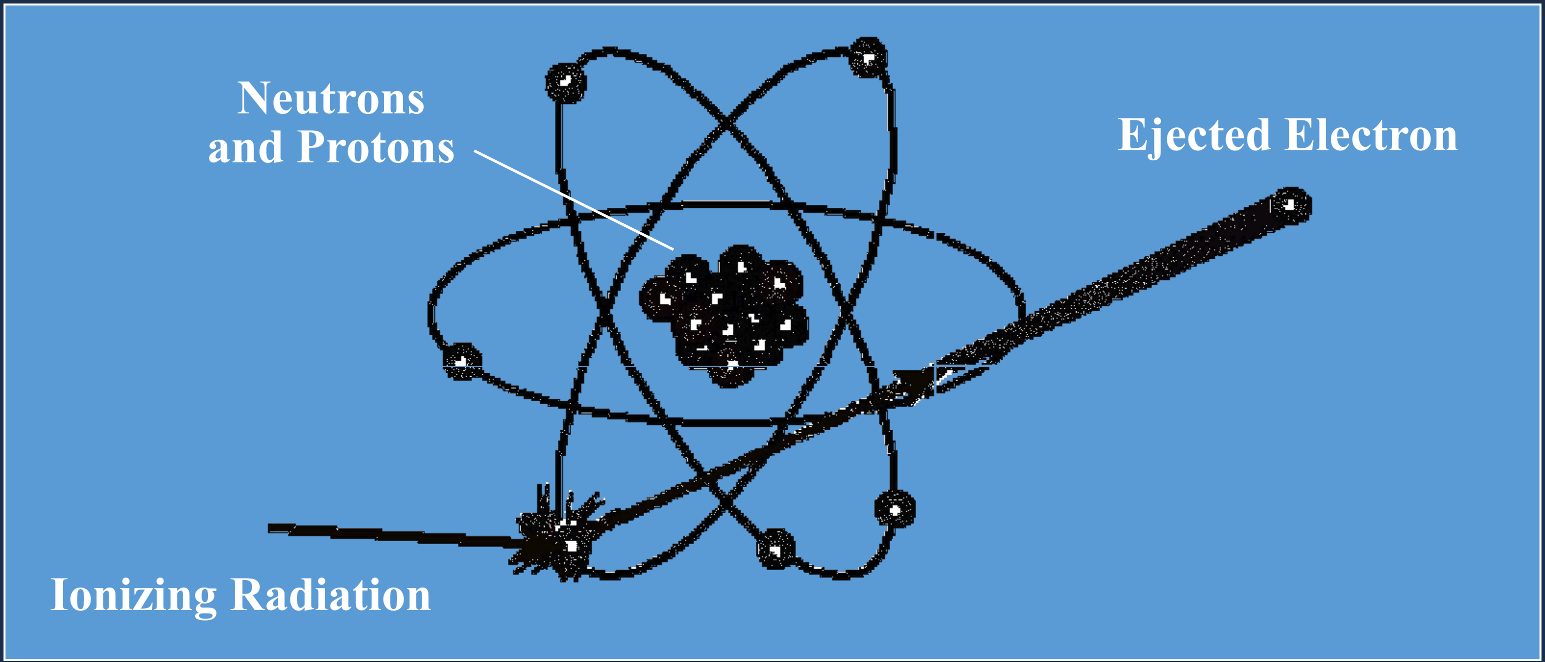
Electromagnetic Spectrum



Particles can also be described by a wave function!

Why is it called *ion*izing?

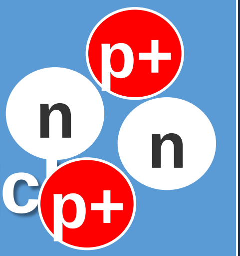
Because it creates *ions* -- atoms with a charge.



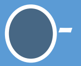
Radiation Types

Alpha (α)

- 2 protons, 2 neutrons
- positively charged partic



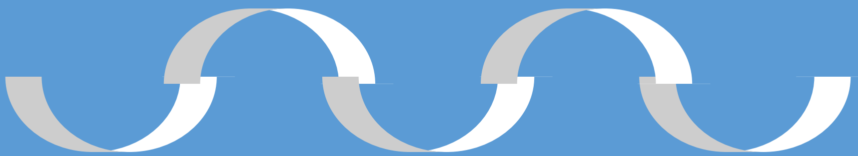
Beta (β)



- like an electron
- negatively charged particle

Gamma (γ)

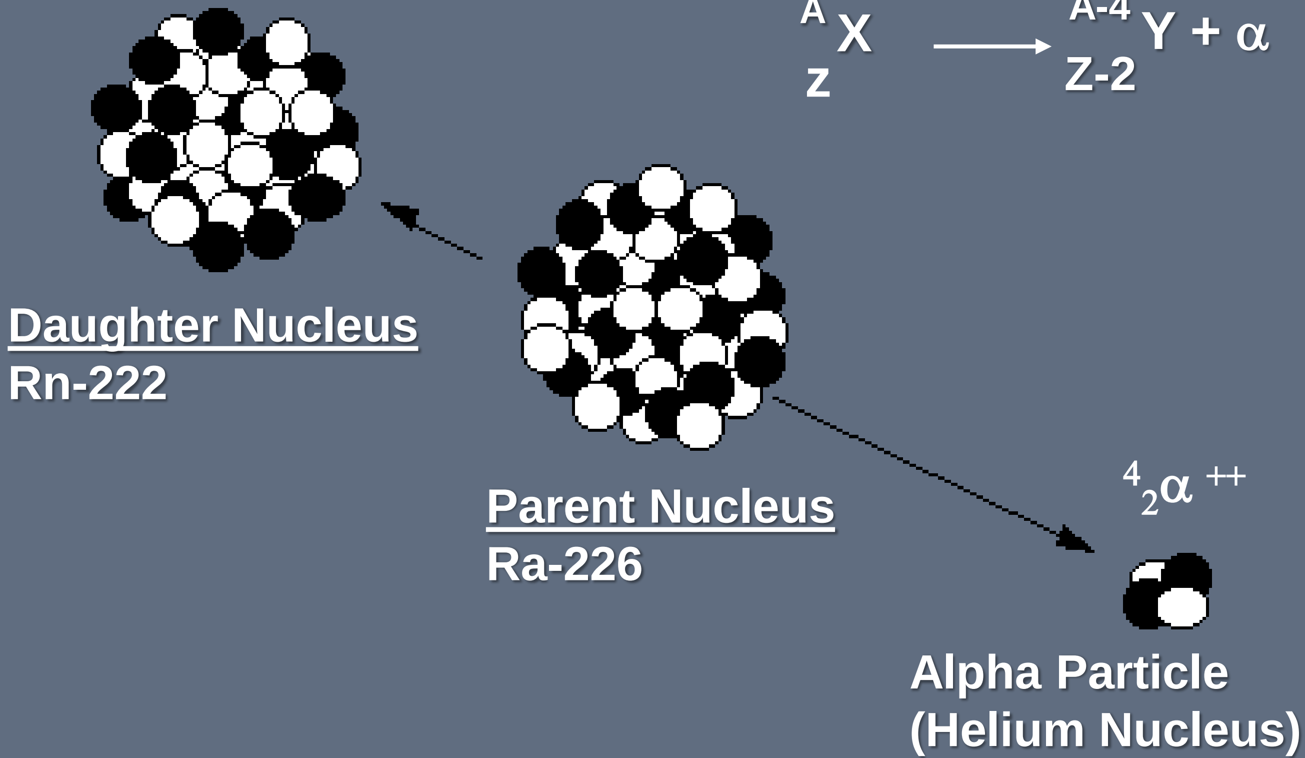
- Wave energy (*not* a particle)



Radioactivity: α Decay

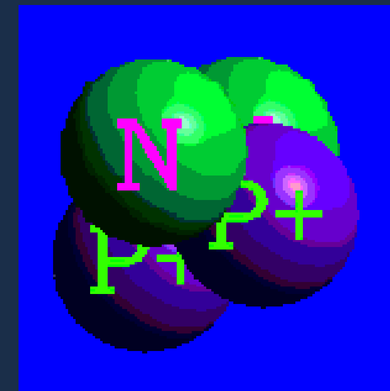
$$ {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + \alpha $$

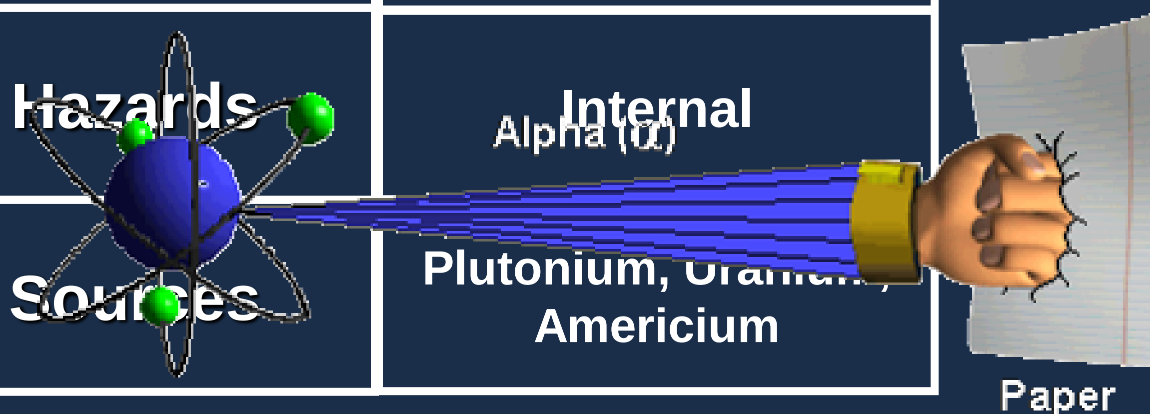
Alpha tracks in a cloud chamber



Alpha Radiation (α)

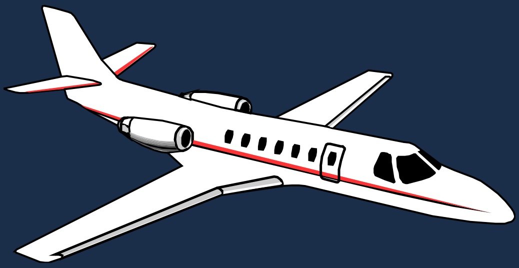
Characteristics	Particle, Large Mass, +2 Charge
Range	Very Short 1 - 2” in air
Shielding	Paper Outer layer of skin
Hazards	Internal
Sources	Plutonium, Uranium, Americium

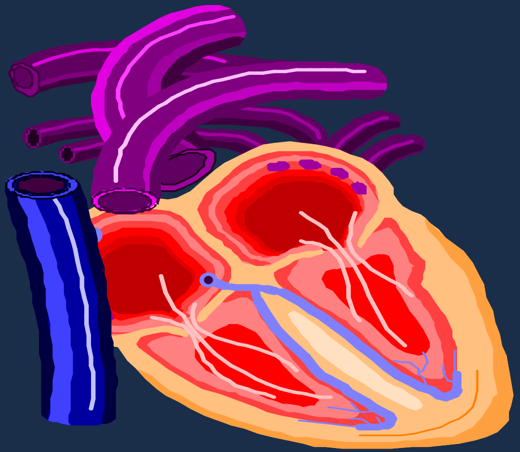




Uses of Alpha Radiation

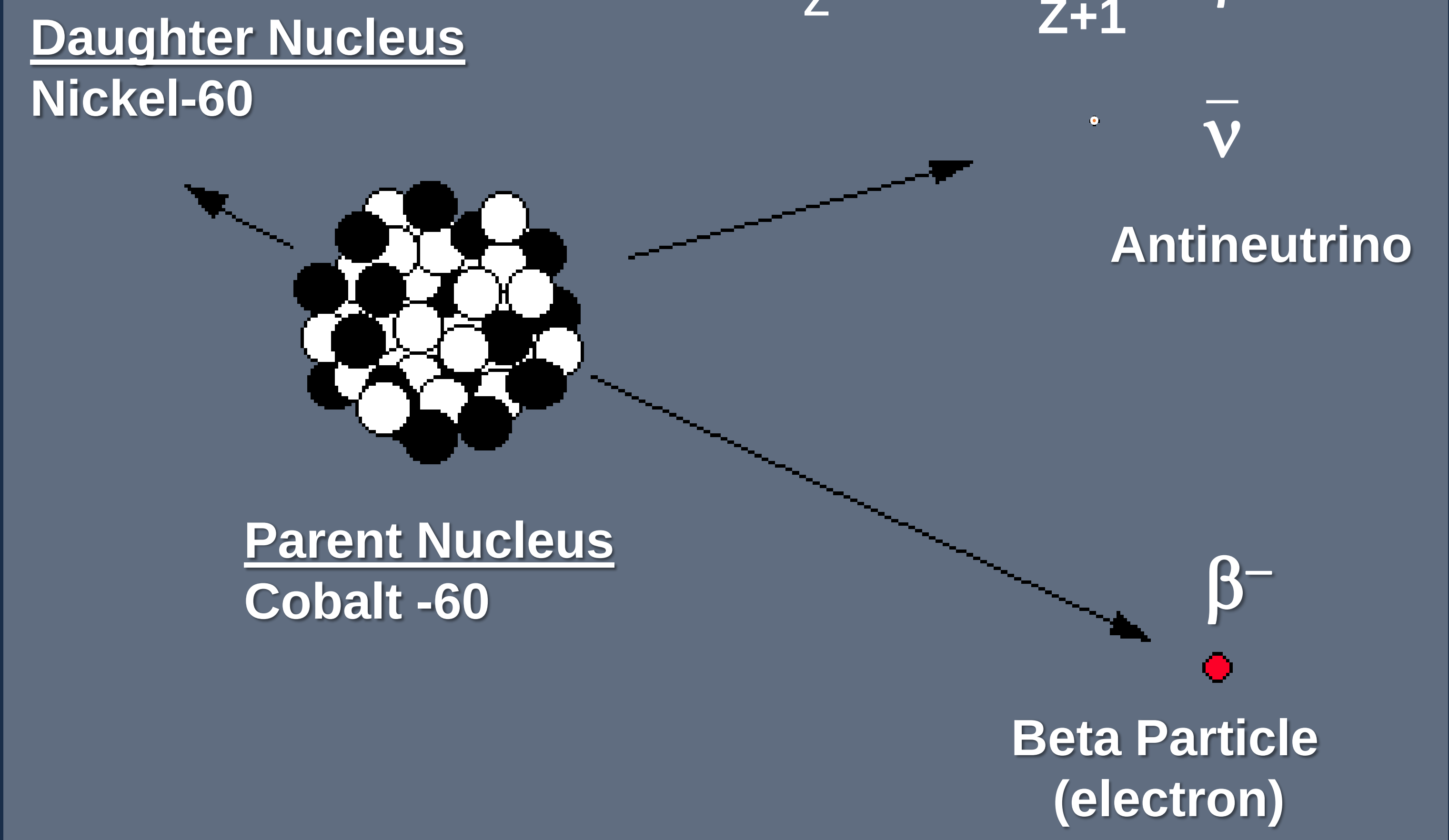
- Pacemakers
  (Older models)
- Airplanes
- Copy Machines
- Smoke Detectors
- Space exploration



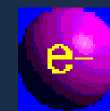
Radioactivity: β^{-} Decay

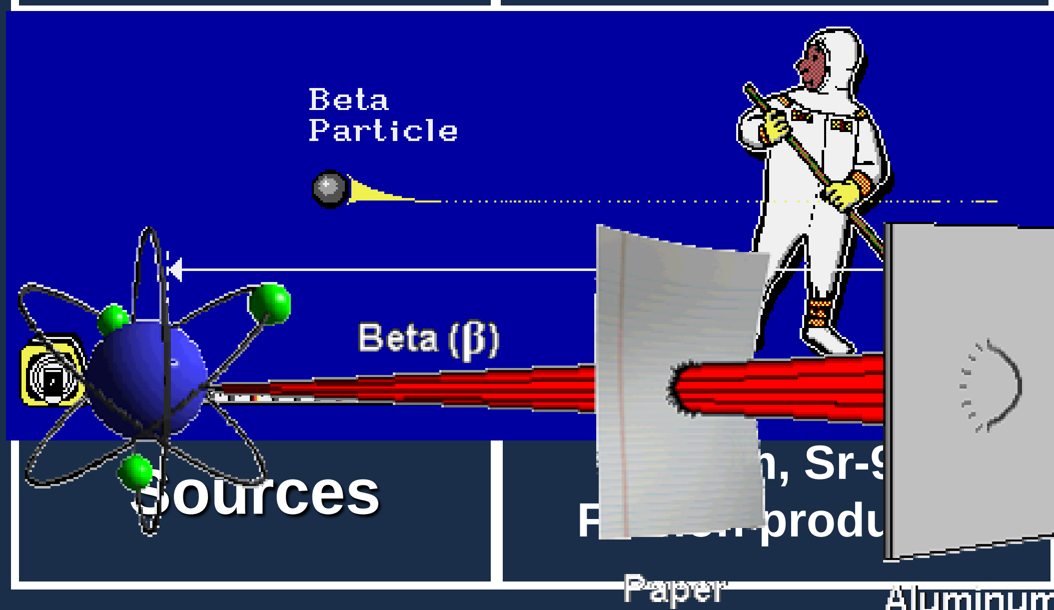
$$ {}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + \beta^{-} + \bar{\nu} $$

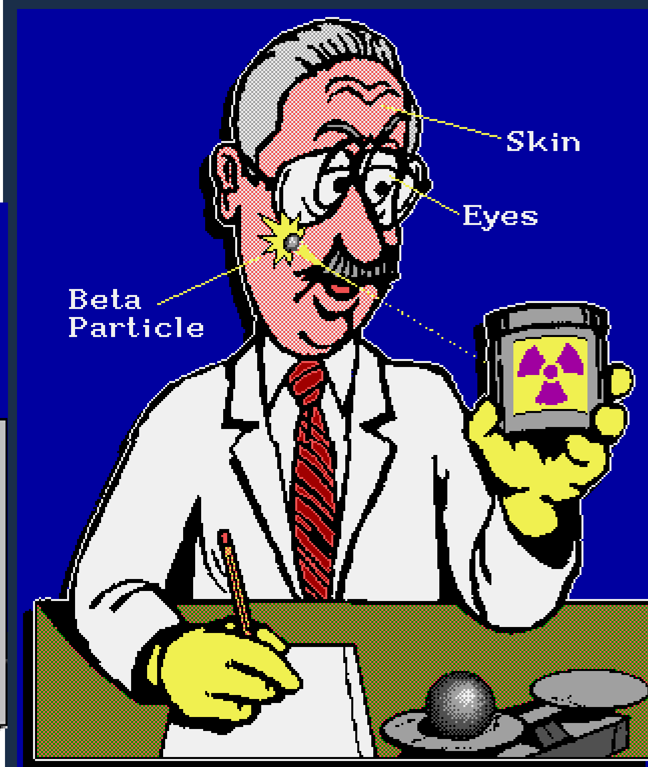


Beta Radiation (β)

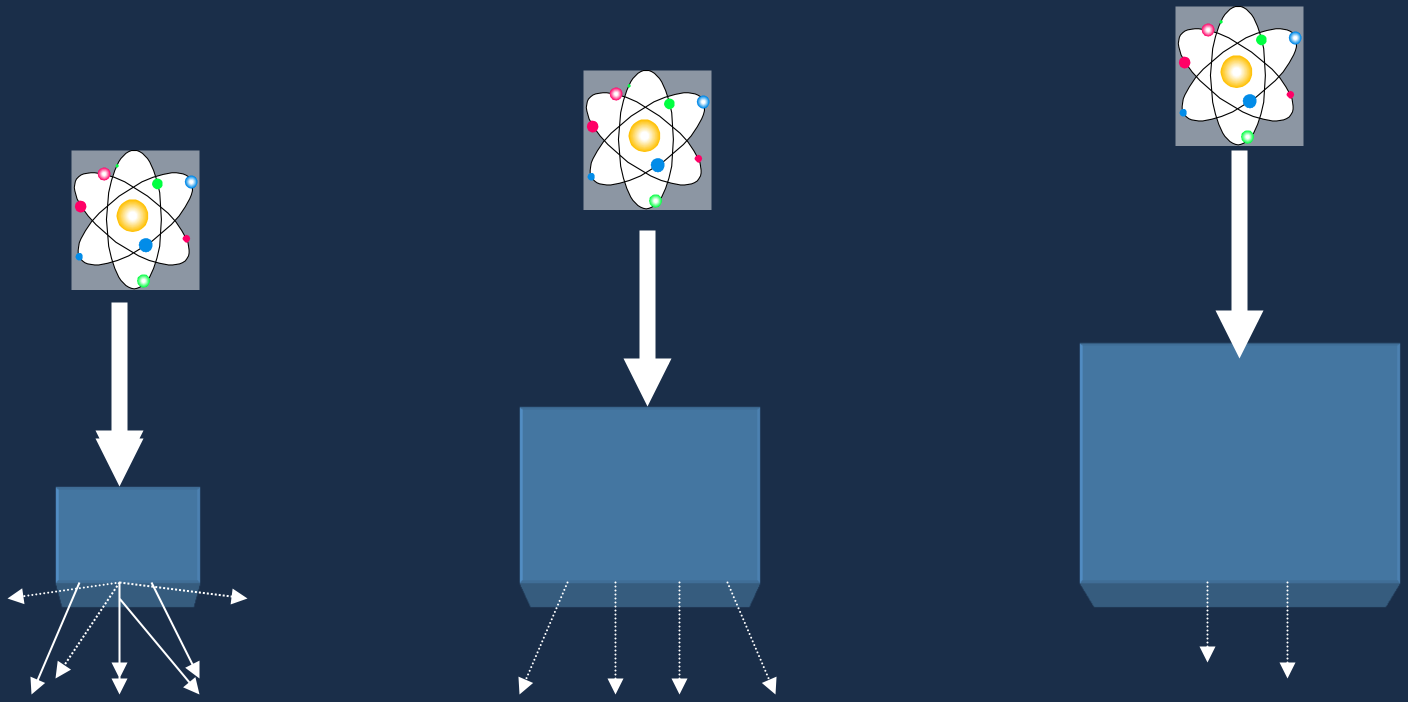
Characteristics	Particle, Small Mass, -1 Charge
Range	12ft / MeV in air
Sources	…n, Sr-9… F… produ…





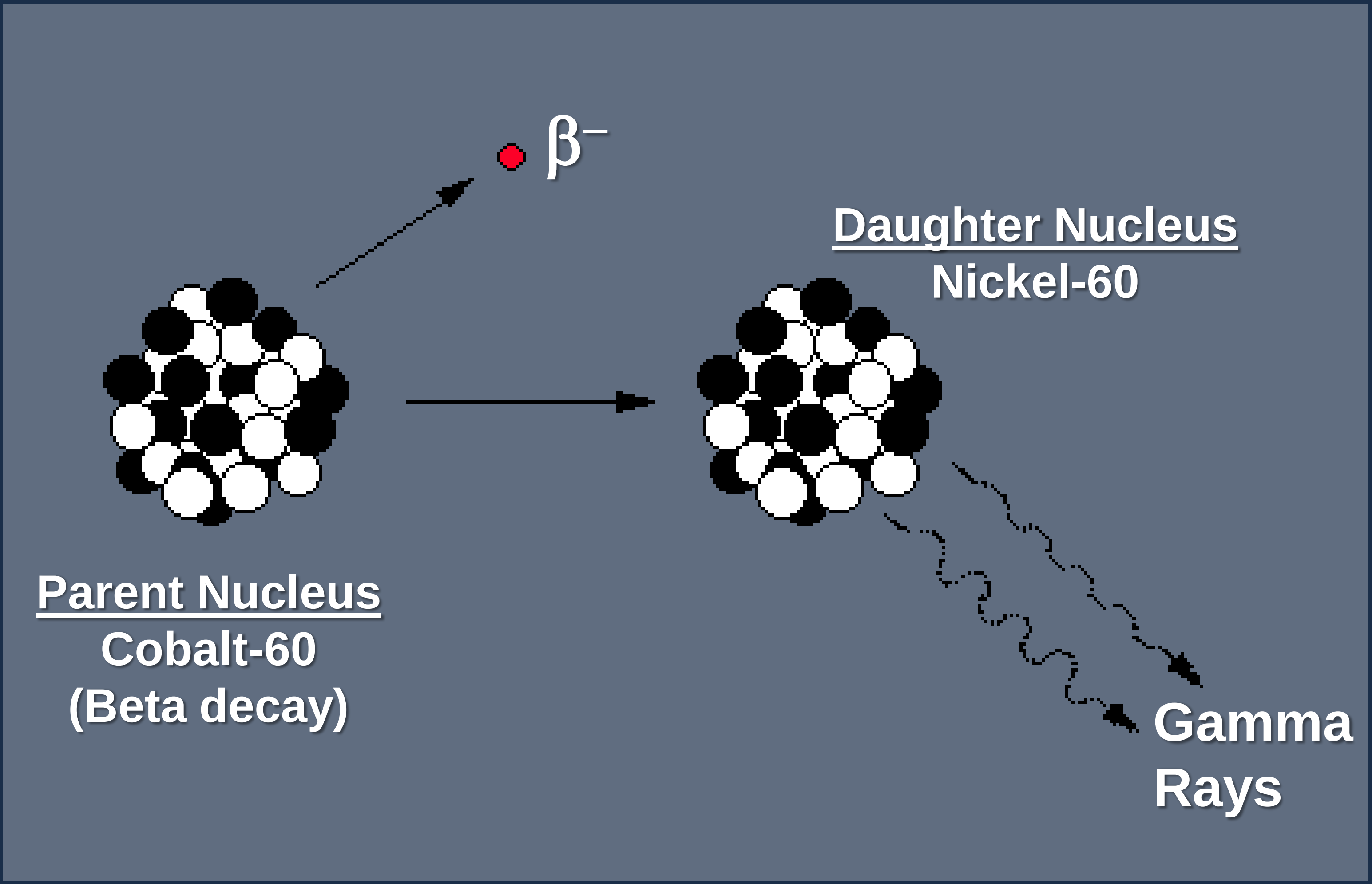


Beta Radiation is used in thickness gauging



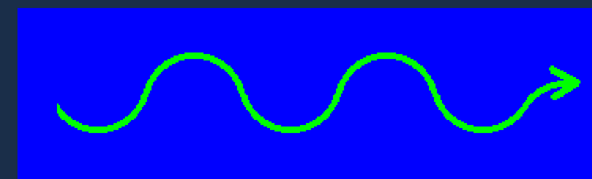
The thicker the material the less radiation will pass through the material.

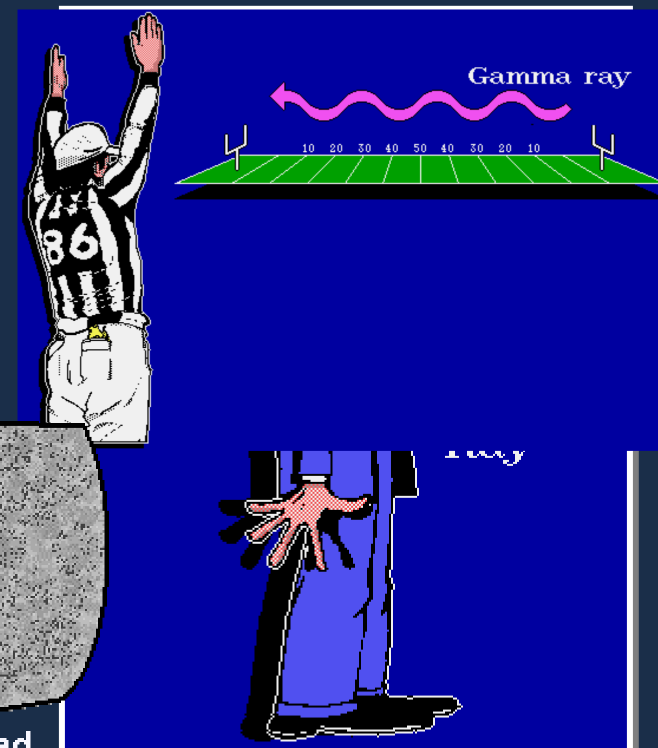
Gamma Emission

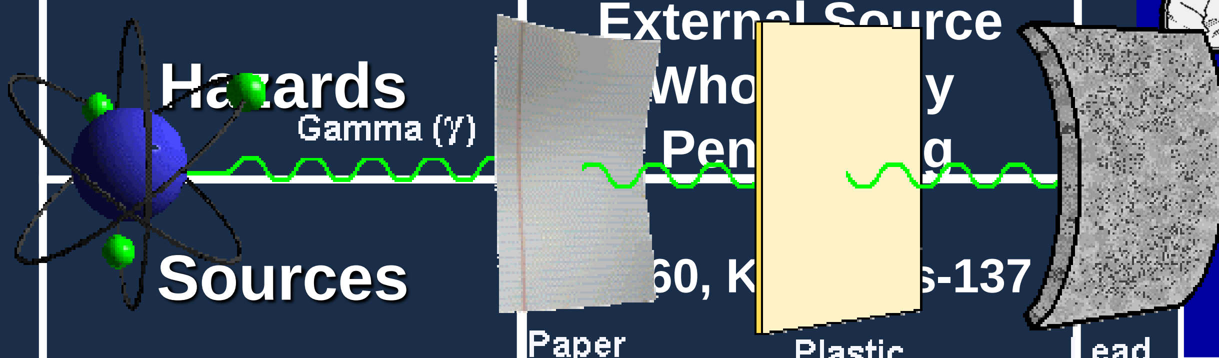


Gamma Rays (γ) and X-Rays

Characteristics	No electromagnetic mass, no charge
Range	Hundreds of feet in air
Shielding	Lead, Steel Concrete
Hazards	External Source Who… y Pen… g
Sources	…60, K… …s-137

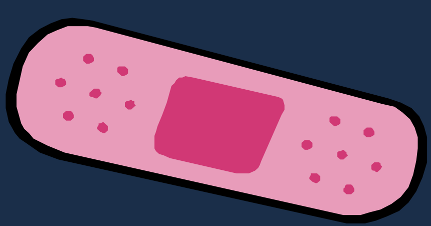






Uses for Gamma Radiation:

- Food irradiation
- Sterilization of medical equipment
- Creation of different varieties of flowers
- Inspect bridges, vessel welds and Statue Of Liberty.



RADIOACTIVE DECAY REACTIONS

ALPHA DECAY

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\alpha$$

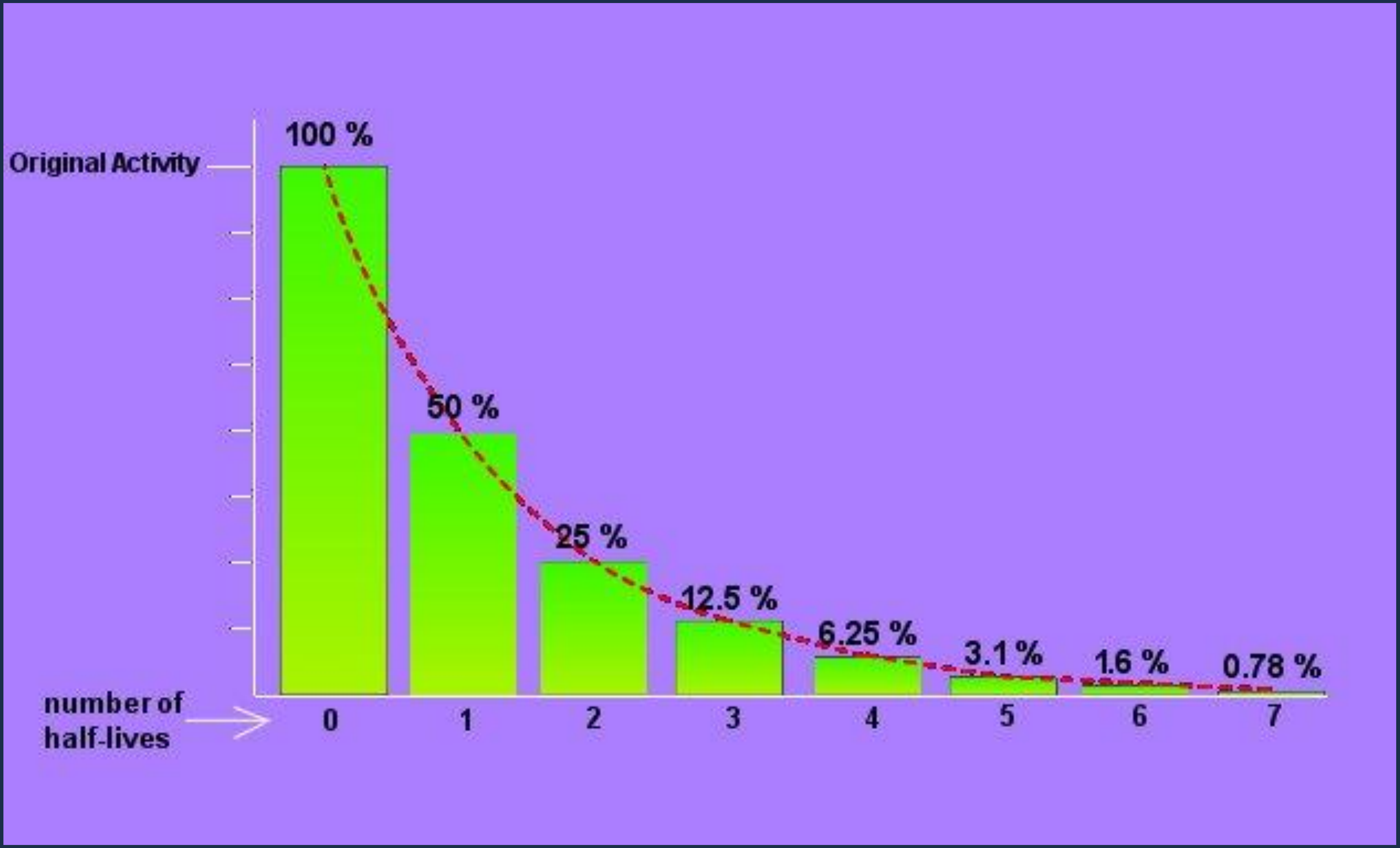
BETA DECAY

$$^{234}_{90}\mathrm{Th} \rightarrow {}^{234}_{91}\mathrm{Pa} + {}^{0}_{-1}\beta + \bar{\nu}$$

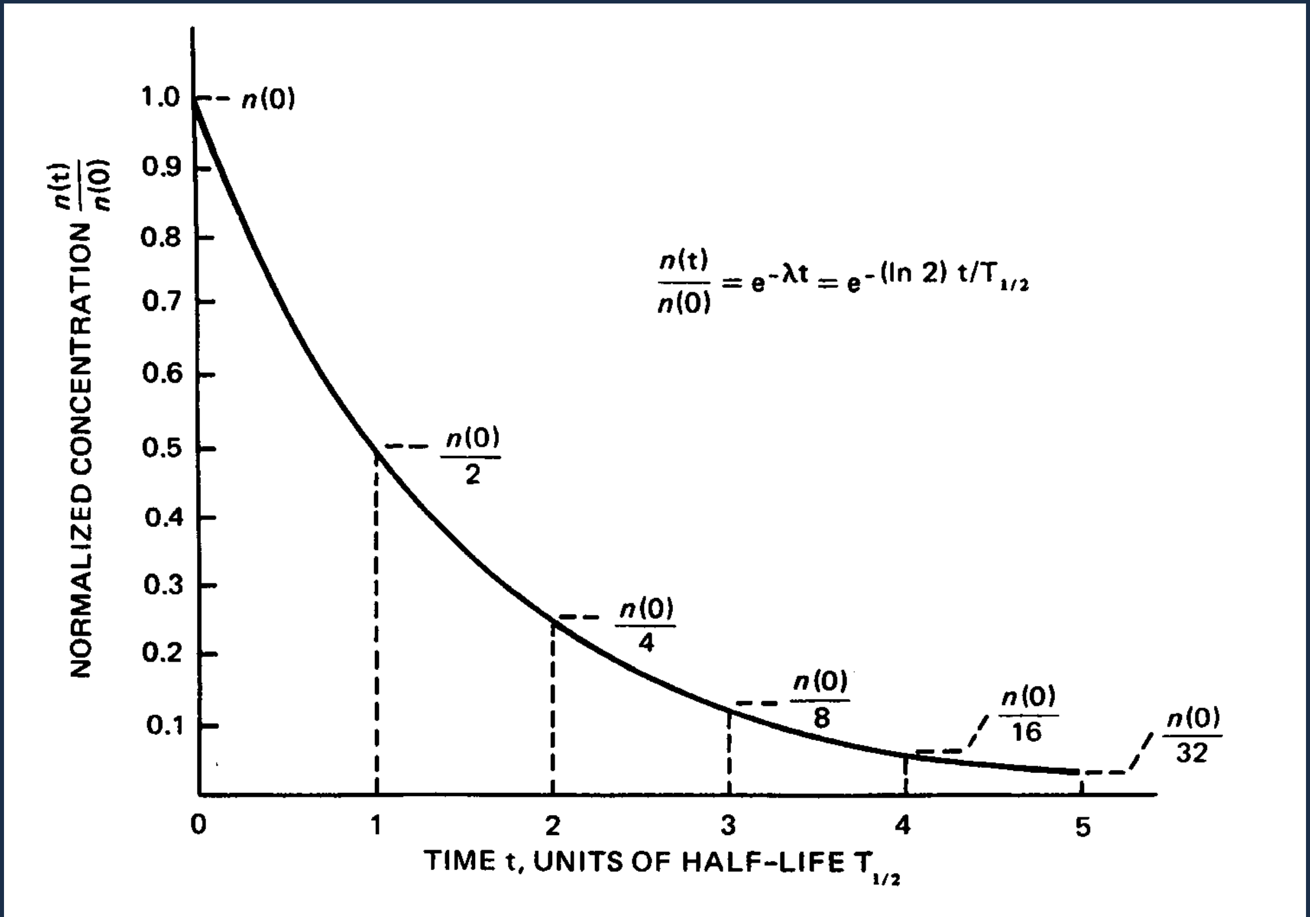
GAMMA DECAY

$$^{137m}_{56}\mathrm{Ba} \rightarrow {}^{137}_{56}\mathrm{Ba} + \gamma$$

Radioactive Half-life

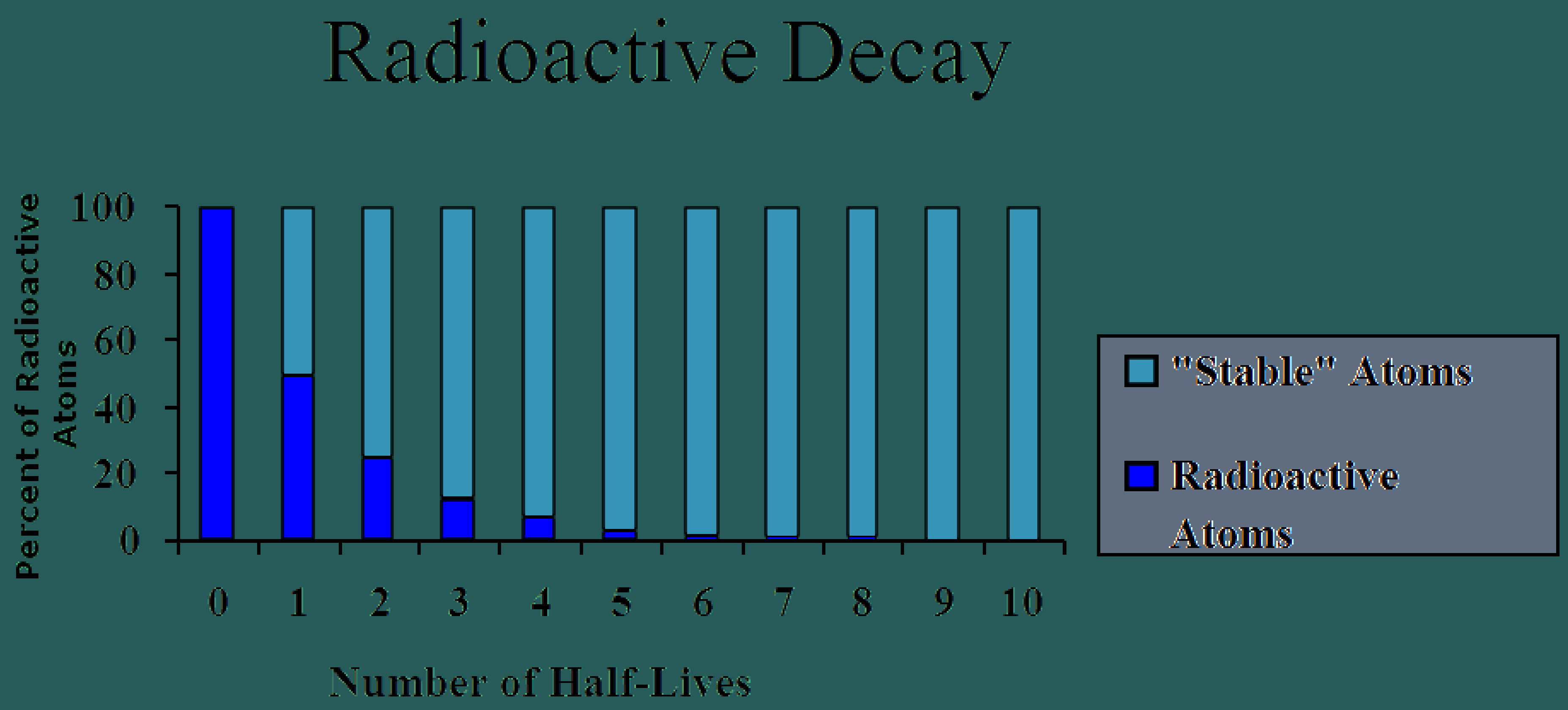


Half-Life



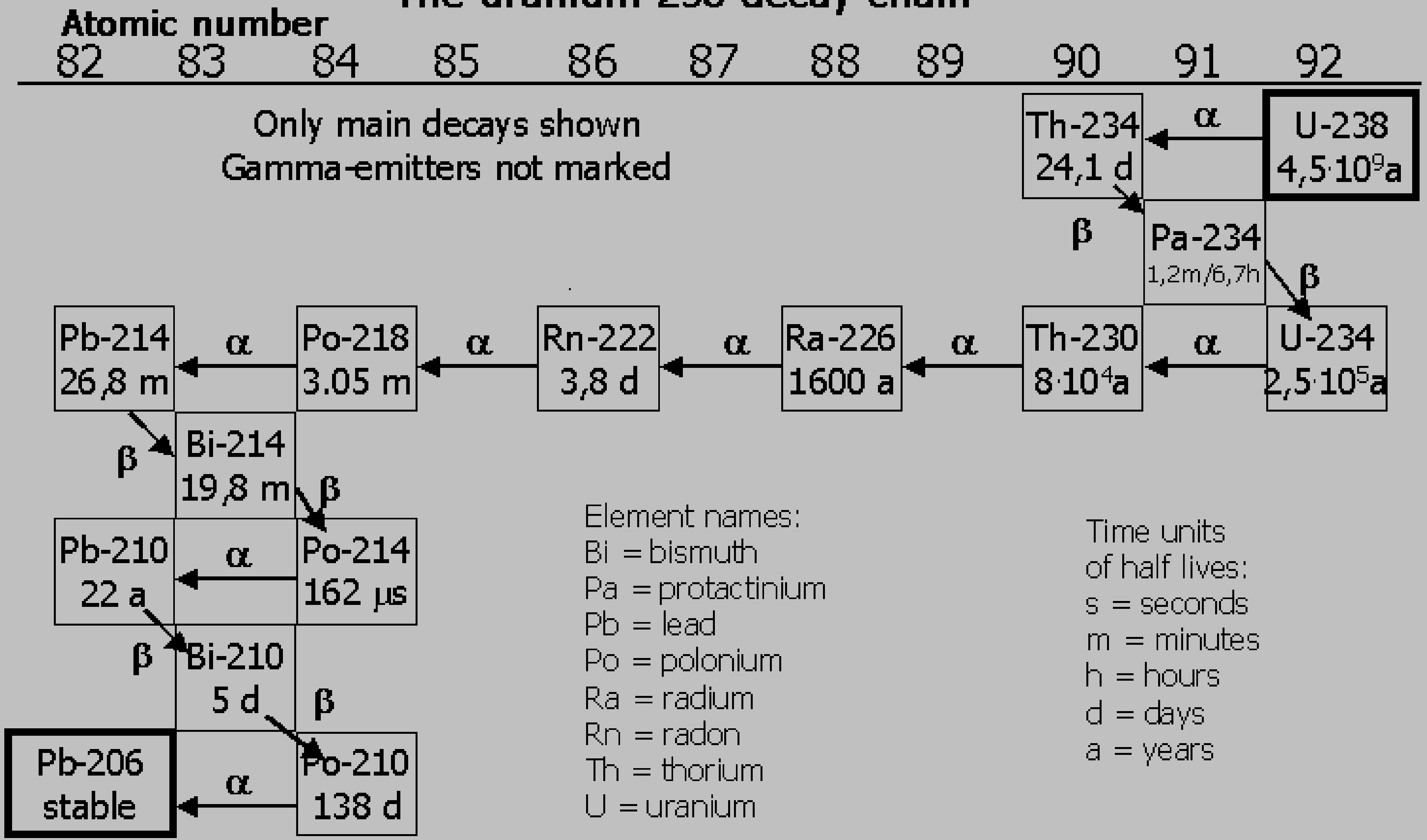
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
NORMALIZED CONCENTRATION $\frac{n(t)}{n(0)}$
$n(0)$
$\frac{n(0)}{2}$
$\frac{n(0)}{4}$
$\frac{n(0)}{8}$
$\frac{n(0)}{16}$
$\frac{n(0)}{32}$
$\frac{n(t)}{n(0)} = e^{-\lambda t} = e^{-(\ln 2)\, t/T_{1/2}}$
0
1
2
3
4
5
TIME t, UNITS OF HALF-LIFE $T_{1/2}$

Half Life



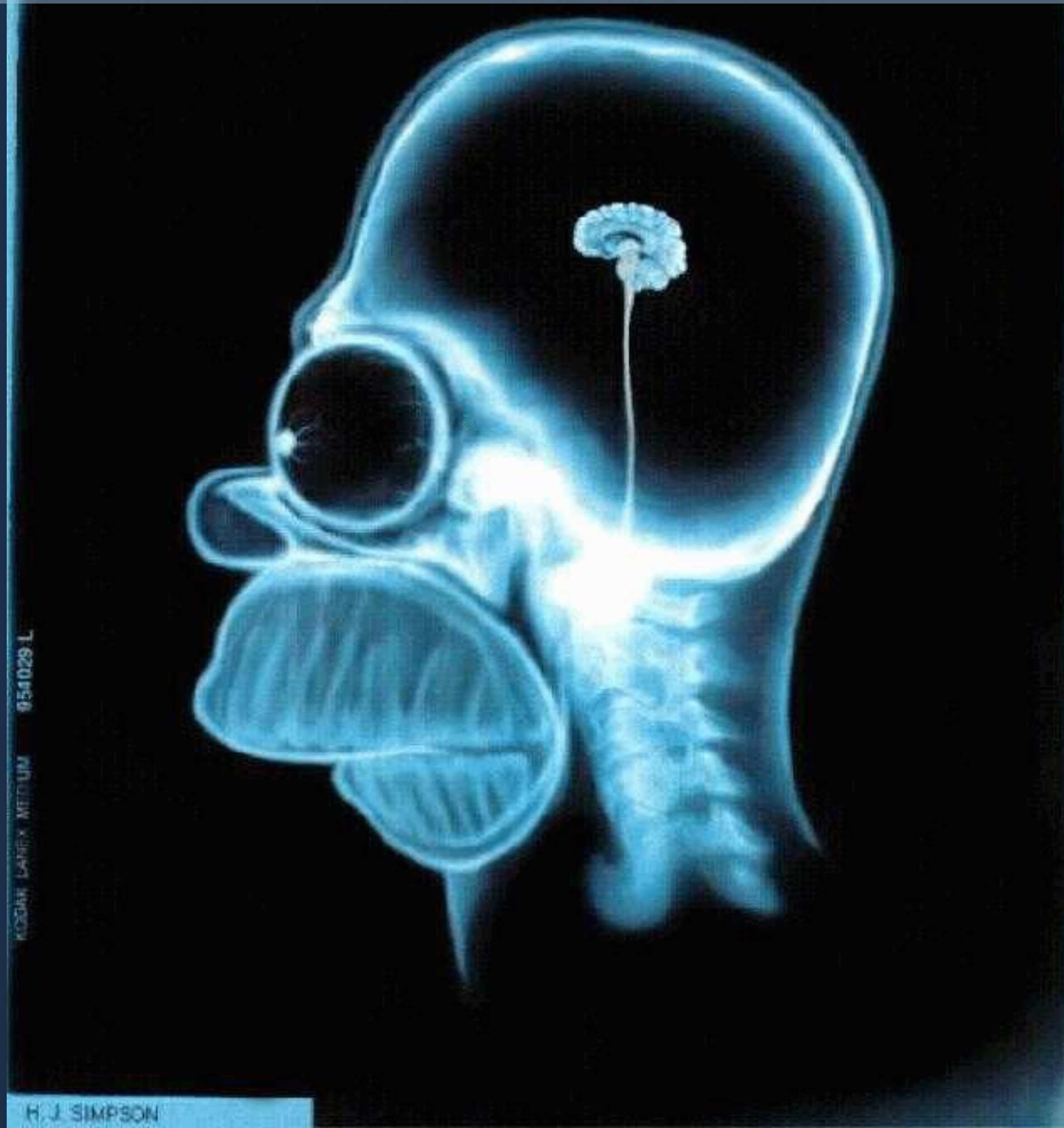
Radioactive Decay
Percent of Radioactive Atoms
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
Number of Half-Lives
"Stable" Atoms
Radioactive Atoms

The uranium-238 decay chain

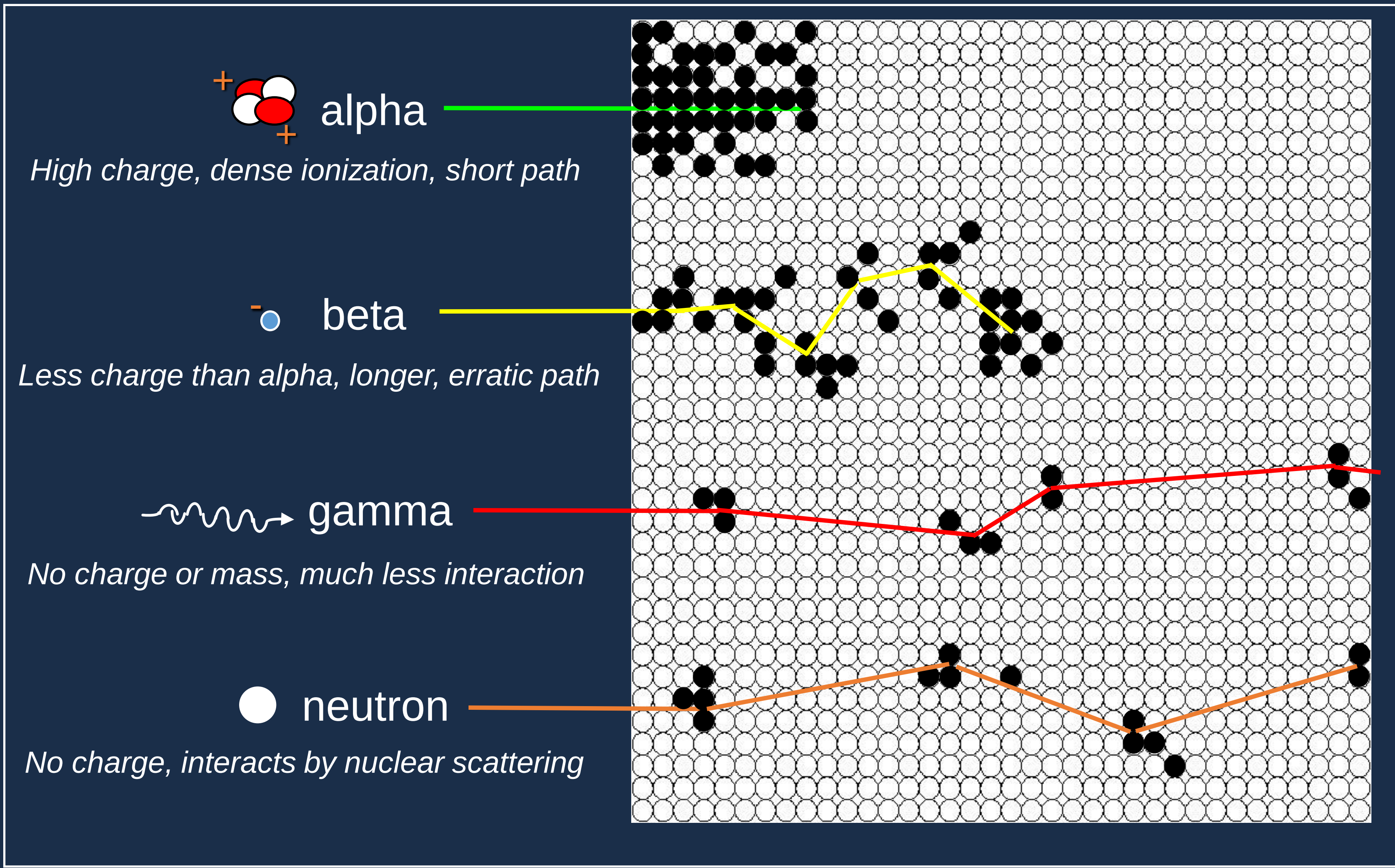



Is it SAFE?
What about the Environment?

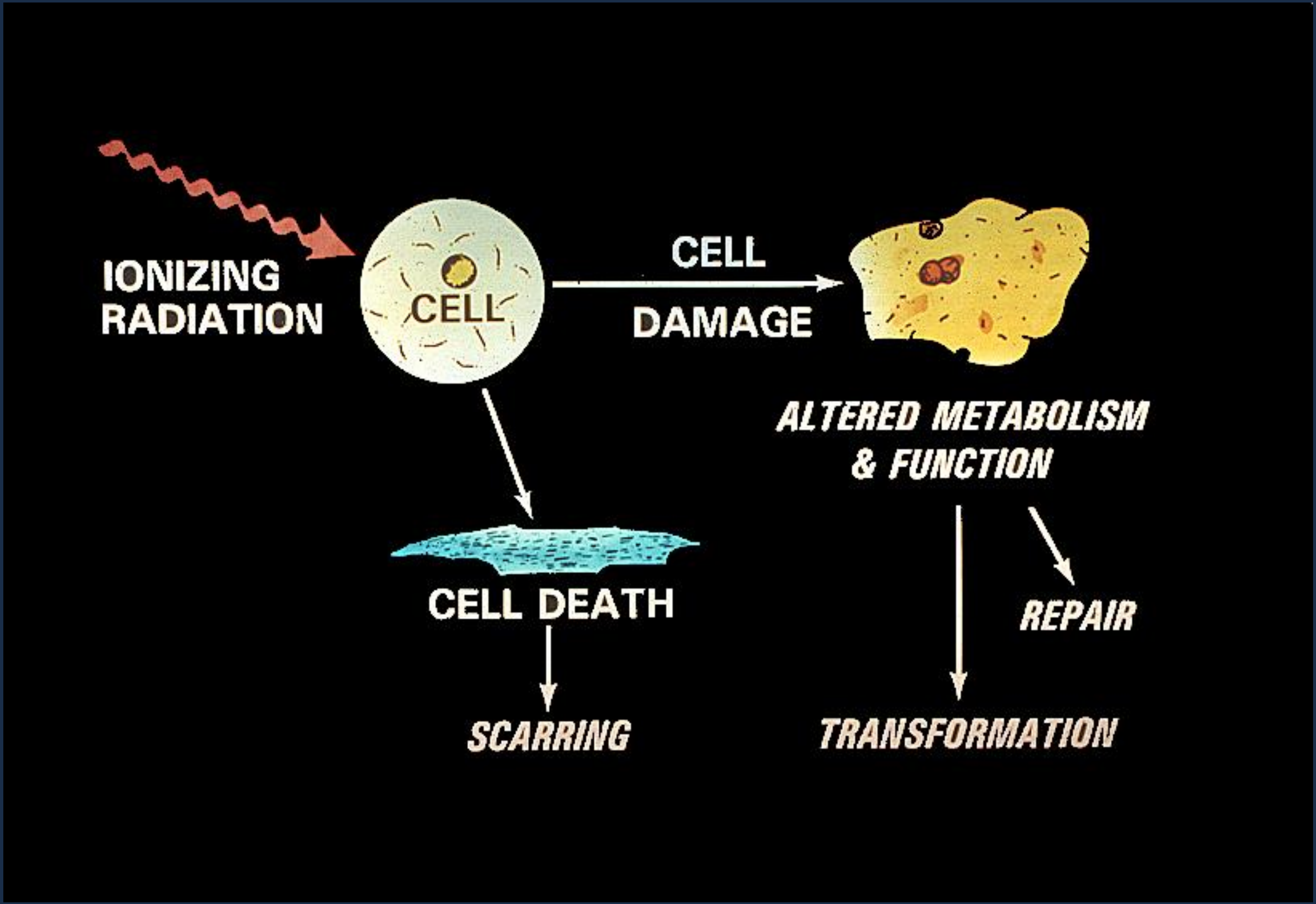
HOW RADIATION AFFECTS YOUR BRAIN



Radiation Interaction and Penetration Through Matter



Cell Damage


IONIZING
RADIATION
CELL
CELL
DAMAGE
ALTERED METABOLISM
& FUNCTION
CELL DEATH
SCARRING
REPAIR
TRANSFORMATION

Direct vs. Indirect Ionization

- Direct

  Radiation that ejects orbital electrons from absorber atoms like charged particles (alphas and betas)

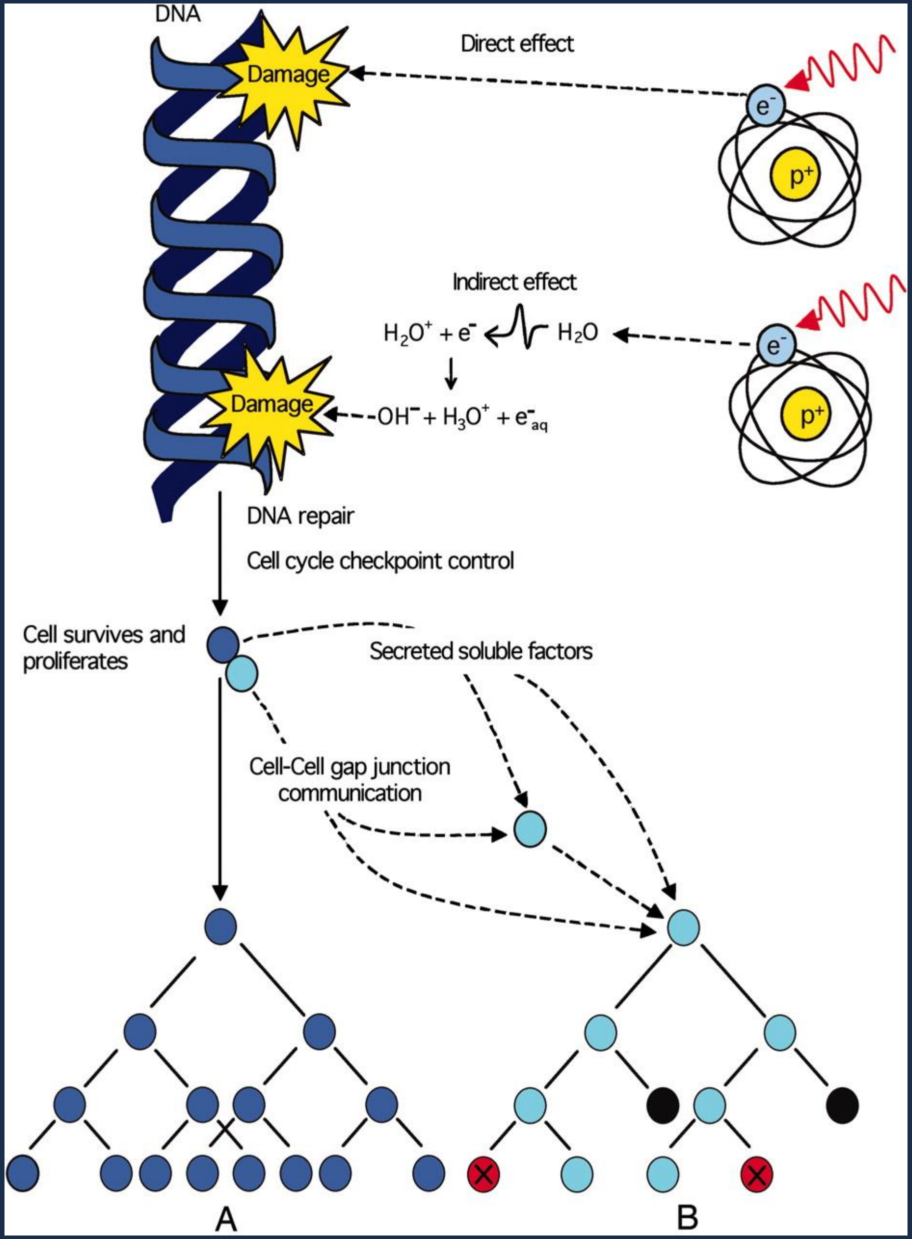
- Indirect

  Transfer energy to charged particles (protons/electrons) of the absorber atoms, like neutrons and gamma rays.

Ionizing radiation induces:

- Direct DNA damage

- Indirect damage through the radiolysis of water



Sensitivity of Cells

- Lymphocytes
- Spermatogonia
- Hematopoietic (Blood Forming)
- Intestinal Epithelium
- Skin
- Nerve Cells
- Muscle Tissue
- Bone
- Collagen

MOST SENSITIVE

LEAST SENSITIVE

Radioactive Contamination

- It is not like a spreading contagion (think of a flashlight)
- Can be solid, liquid, or gaseous
- In solid form can be thought of as dust or dirt

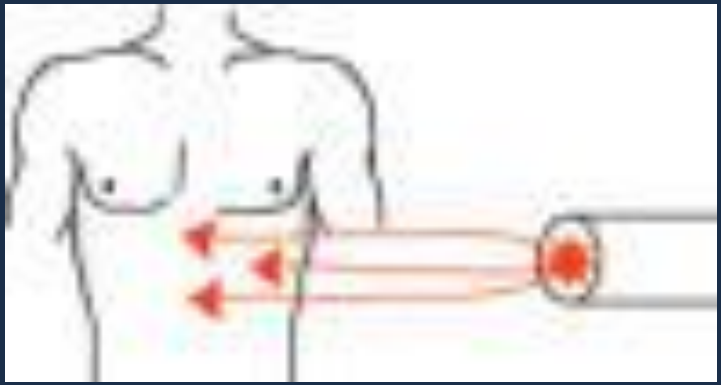
Radioactive Contamination Types

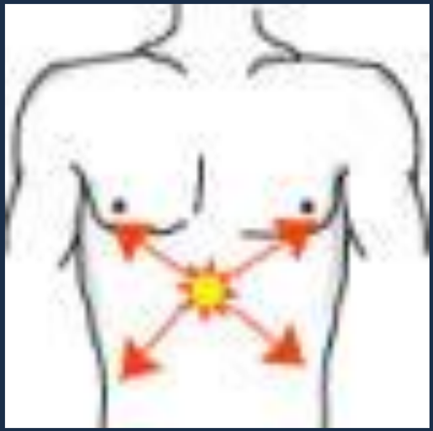
External

- Secondary contamination
- Primarily skin and wounds

Internal

- Can be difficult to remove
- Ingestion and Inhalation





Nuclear Decay - Radioactivity

Radioactivity: The spontaneous transformation ("decay") of unstable nuclei, resulting in a more stable "daughter", accompanied by emission of ionizing radiation

Radioactive Material: A substance that contains unstable atoms, and therefore emits ionizing radiation

Radioisotope (radionuclide): An unstable, radioactive isotope of an element. Well over 2000 radioisotopes have been identified.

Manure Analogy

Radiation Concept	Manure Analogue	Common Aspect
Radioactive material	Manure	The source of invisible emanations
Radiation	Unpleasant Odor	Invisible emanations
Contamination	Manure tracked into your house	The source where you don't want it and where it's not naturally present
Non-radioactive or stable material	Completely composted manure - no unpleasant odor	Incapable of being a source of emanations
Half life	Time it takes for half of the manure to be converted to compost	Natural decay - given time both lose their potency

Units of Radioactivity

- **Activity**: The quantity of radioactive material decaying per unit time
  - Curie (Ci) : 3.7×10^{10} disintegration per second (dps)
  - Becquerel (Bq): 1 dps
- **Specific Activity**: The amount of radioactivity in a given mass or volume - e.g. Ci/liter or Ci/gram

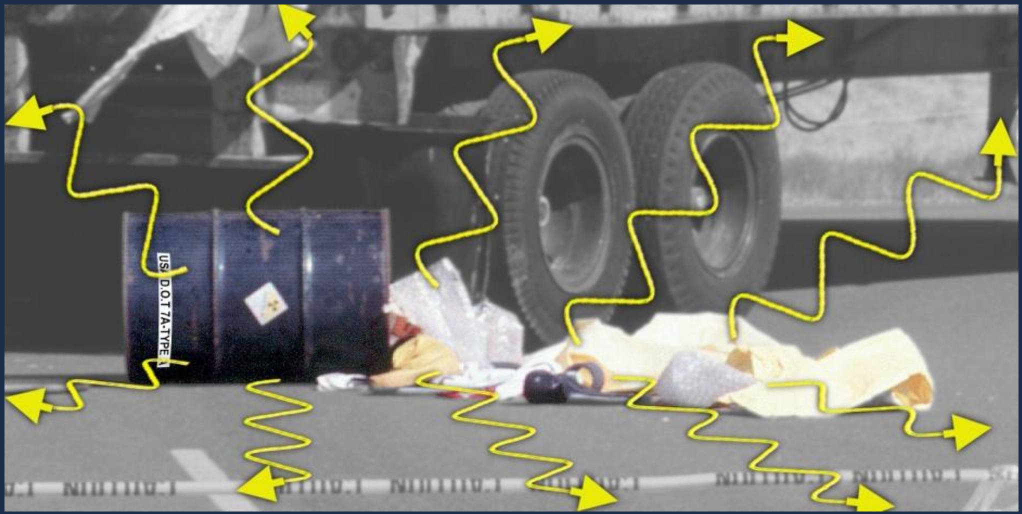
Note: Activity is the number of atoms decaying, not the number of atoms present.

Exposure

- Radiation = Energy
  Contamination = Material

- Radioactive contamination emits radiation

- Exposure to radiation will NOT contaminate you



Units for Exposure and Dose

- **Exposure (X):** Generically, exposure is the condition of being exposed. Exposure is also used to quantify the amount of ionization produced by photons as they pass through air. The unit of exposure is the *Roentgen (R)*.

  1R = 1 esu/cc   in air

- **Absorbed Dose (D):** Absorbed dose is the amount of energy deposited in any material by ionizing radiation. The unit of absorbed dose used in the U.S., the *rad*, is a measure of energy absorbed per gram of material. The S.I. unit is the *Gray (Gy)*. One *Gray* equals 100 *rad*.

  1Gy = 1 J/kg   in any material

- **Dose Equivalent (H):** A special concept relating absorbed dose to biological detriment. In the U.S. the unit is the *rem*. The S.I. unit is the *Sievert (Sv).* One *Sievert* equals 100 *rem*.

Relative Risk: Equivalencies to 1 mrem

- Crossing a street 5 times
- A few puffs on one cigarette
- Being 0.0007 ounce overweight
- Driving 5 miles
- Getting out of bed every morning for a year
- 3 minutes of living if you are 65 years old
- Using a bathtub for a few months

Radiation Reduction

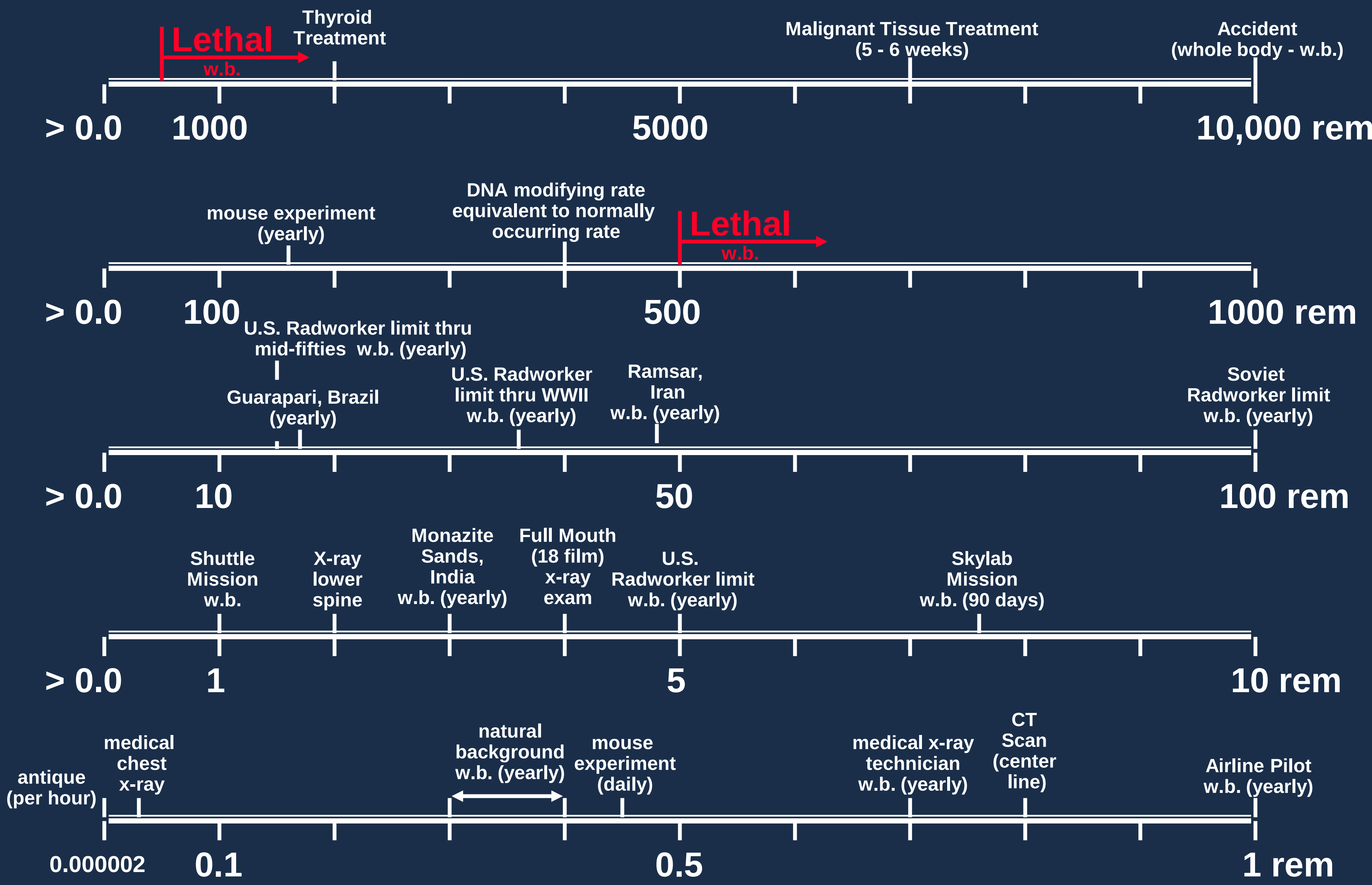
- Guiding principle: ALARA
  (as low as reasonably achievable)

- Restrict Proximity *TIME*

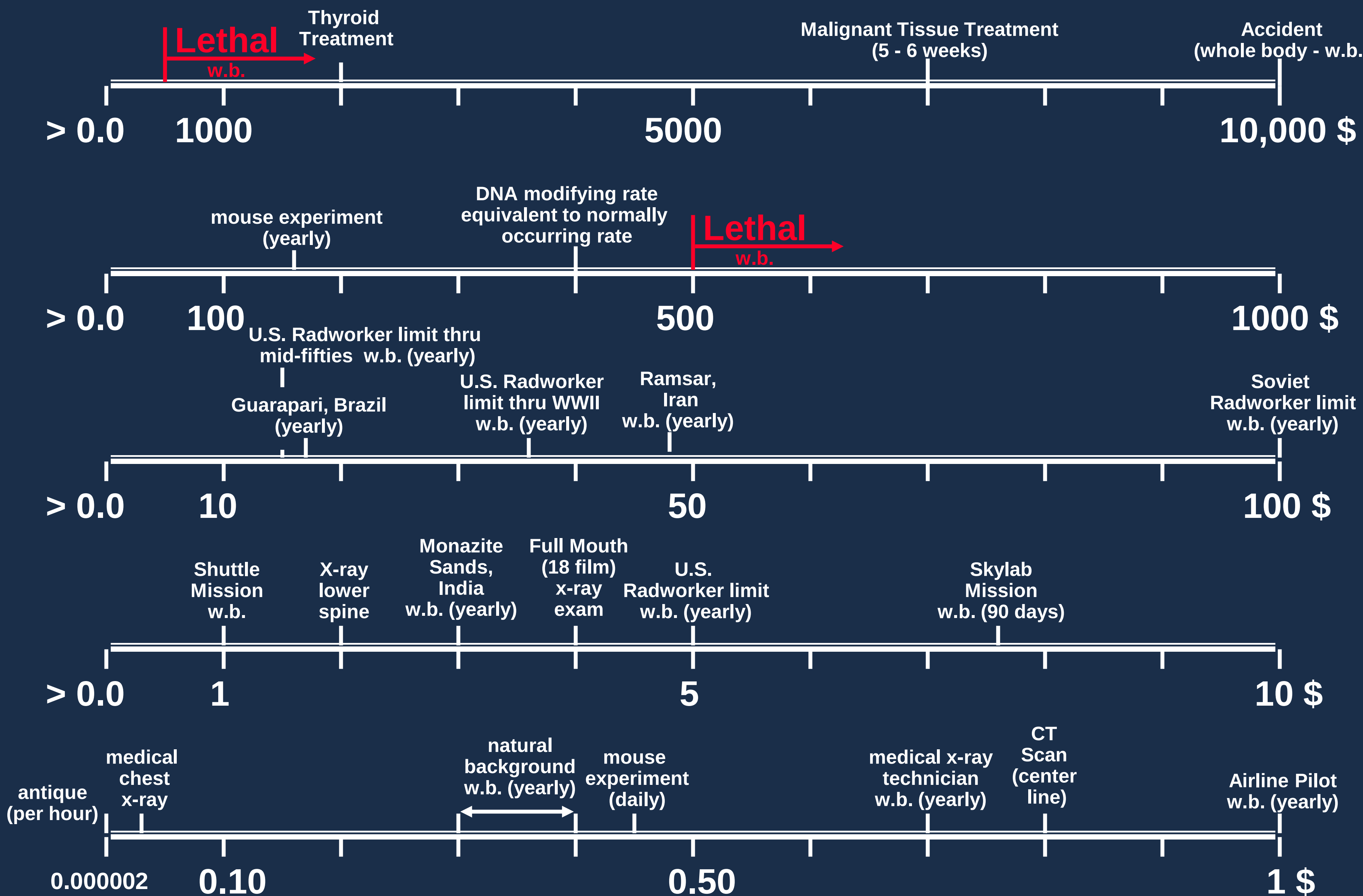
- Increase the *DISTANCE* from the Source

- Use *SHIELDING* Material

Human Experience: Ionizing Radiation



Human Experience: Ionizing Radiation



As Gandhi so eloquently put it,

"The enemy is fear. We think it is hate; but, it is fear".

--- QUESTIONS ---

The End . . .

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American Nuclear Society