



Basic Nuclear Physics

Introduction to WMD Science

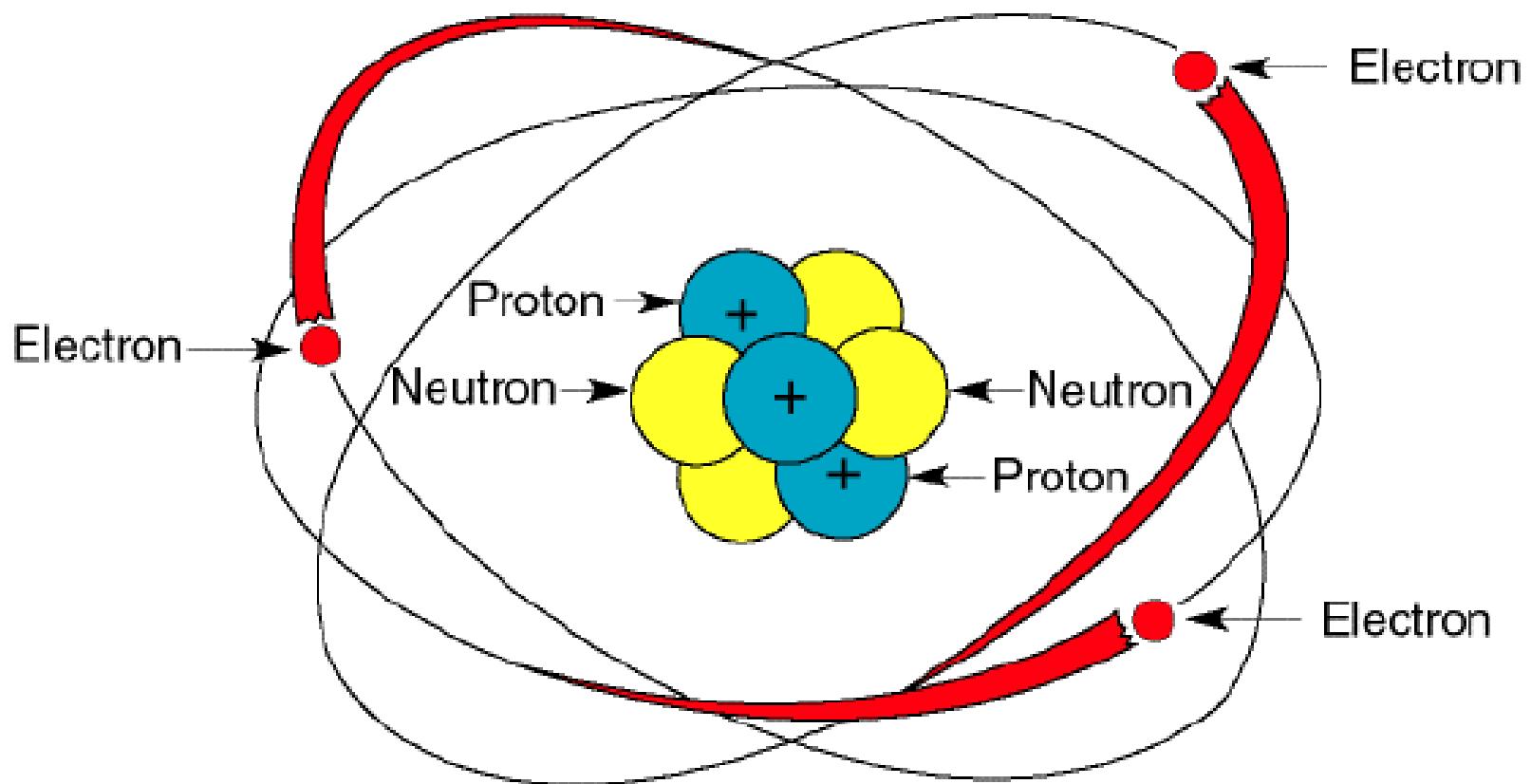
SAND No.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

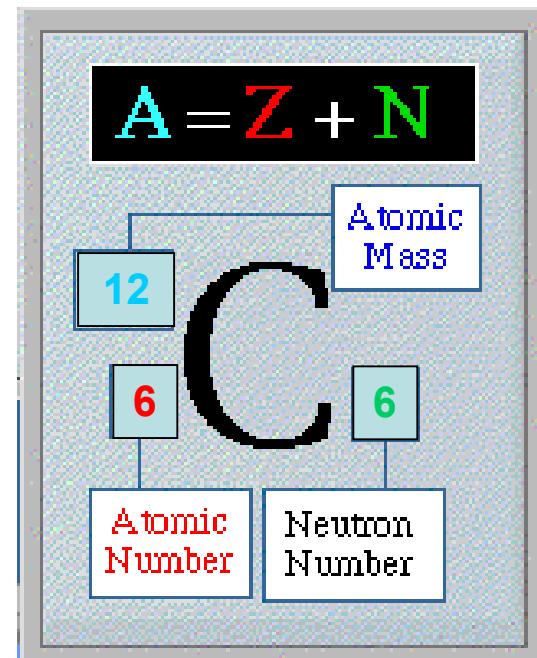
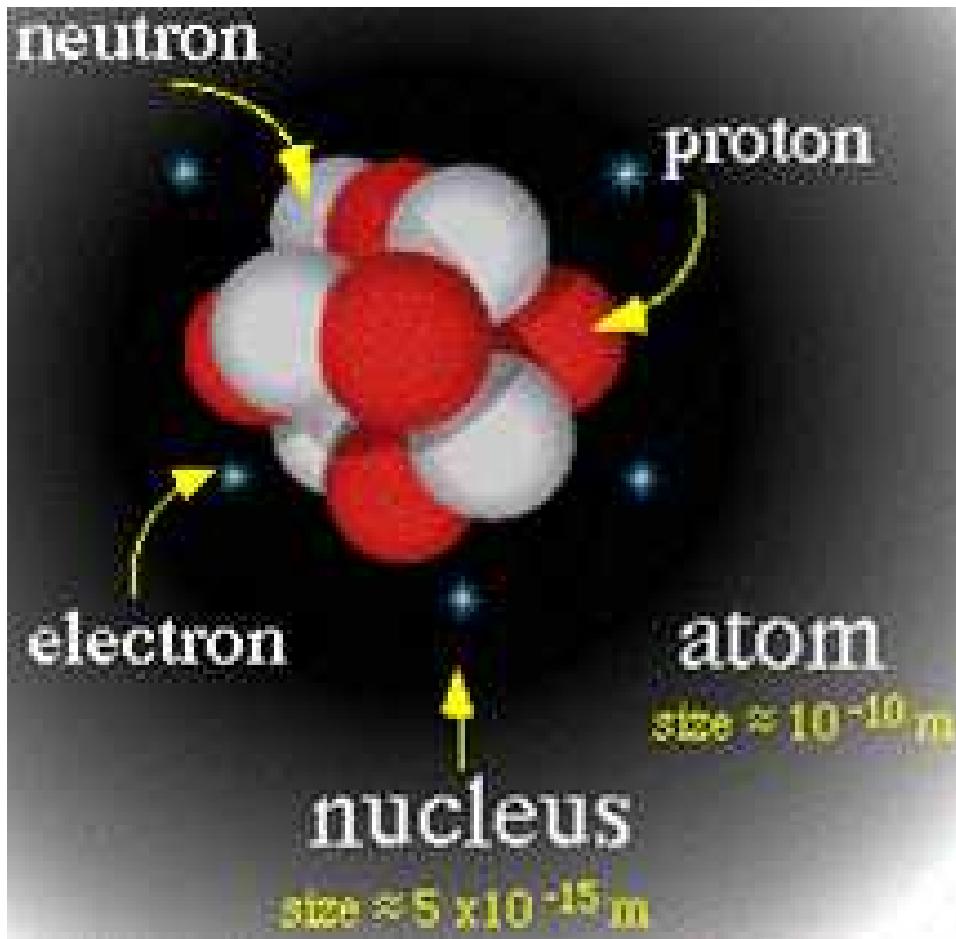
Enabling Objectives

- Describe the basic structure of atoms
- Explain what an isotope means
- Explain what the term half-life means
- Describe the four main types of radiation
- Describe the penetration capabilities of each type of radiation
- State the type of shielding necessary for each type of radiation

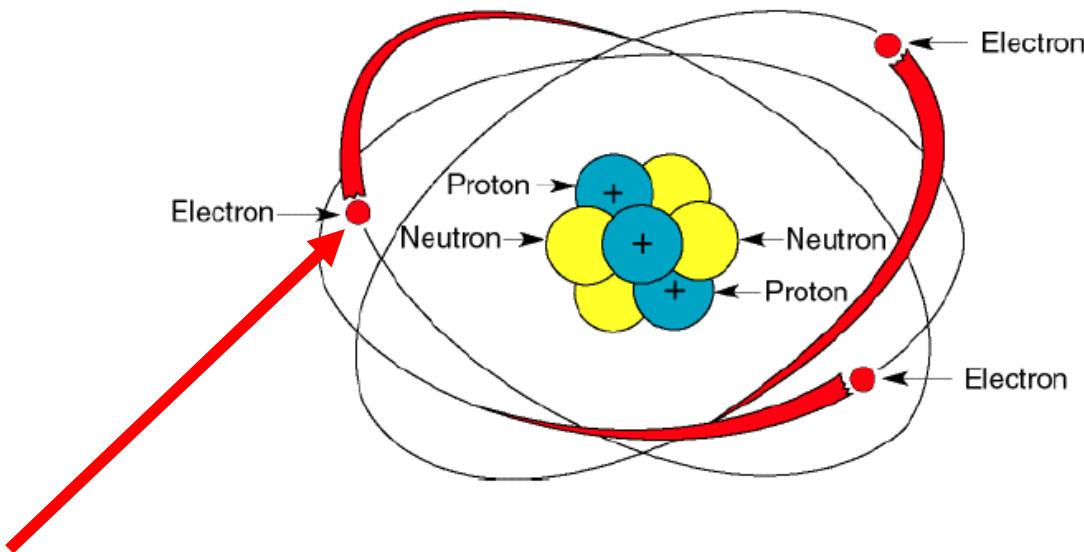
Atoms: Building Blocks of Matter



Basics of the Atom

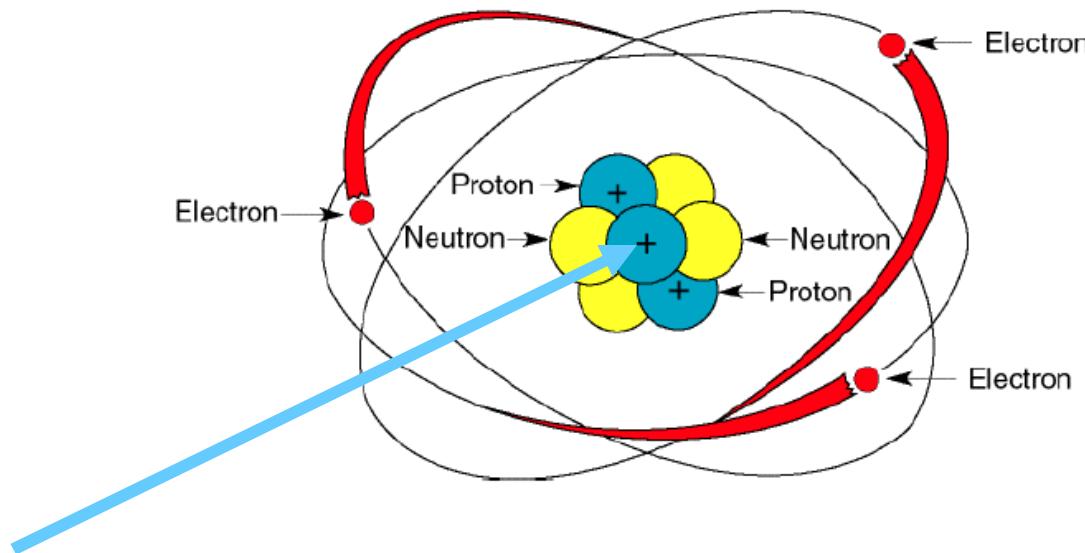


Electrons



- **Electrons** orbit the **nucleus** at a 'large' distance
- Have a **negative** electrical charge
- Have **little** mass
- Form the basis of **chemical bonds**
- Define the **chemistry** of the element
- Do not have a major role in **nuclear** properties

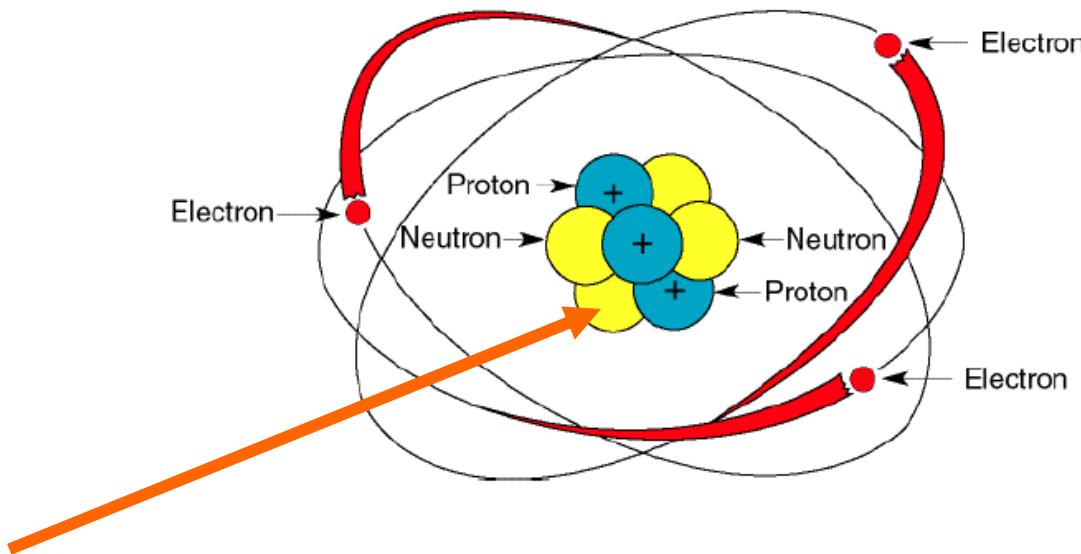
Protons



- **Protons** are located in the nucleus
- Have a **positive** electrical charge
- Have mass (~ 2000 times more massive than the electron)
- Define the chemistry of the element
- Have a major role in nuclear properties

Atoms are electrically neutral

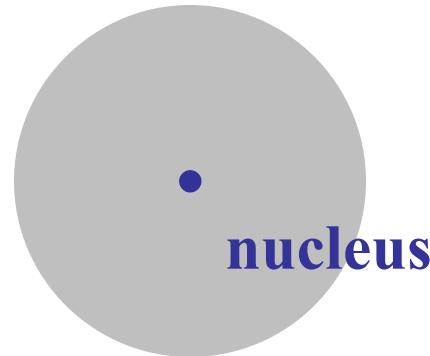
Neutrons



- **Neutrons** are located in the nucleus
- Have no electrical charge
- Have mass (~ 2000 times more massive than the electron)
- Do not have a major impact on chemistry
- Have a major role in nuclear properties

Atom

Electron cloud



- Compared to size of electron cloud, nucleus is very small.
 - Atom is mostly empty space
- Atoms are electrically neutral
 - Electric force holds atom together, not gravity
 - Electric attraction between electron and nucleus is about 10^{40} times gravitational attraction
- Chemical properties of an atom (element) are determined by its valence (outer) electrons

Periodic Table

Arrange elements in “Periodic Table”

IA		IIA														VIII	
1 H		3 Li	4 Be													2 He	
11 Na	12 Mg																
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Unq	105 Unp	106 Unh												

Original: G. Gmelin

Lanthanides

Actinides

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

number of protons
“atomic number”

108 different types of atoms known \Rightarrow elements

Isotopes

Atoms with same number of protons,
but different number of neutrons.

Example: Hydrogen has 3 isotopes:

1 proton + 0 neutrons



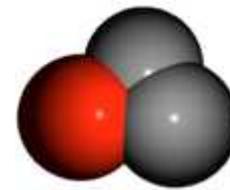
Basic Hydrogen (H)

1 proton + 1 neutron



Deuterium (D)

1 proton + 2 neutrons



Tritium (T) 

Isotopes are chemically the same.

Isotopes (continued)

- The number of protons defines the element
- The number of neutrons defines the isotope

Isotopic number = number of neutrons + number of protons

^{239}Pu or Pu-239 or plutonium-239

- The isotopes of an element
 - have **similar chemical properties**
 - have **different nuclear properties**
- Some isotopes are stable
- Some isotopes have too much energy to stick and need to shed the extra energy

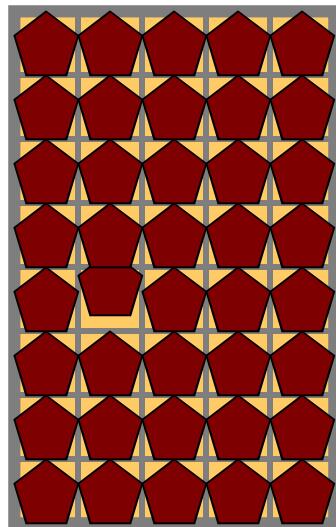
radioactivity



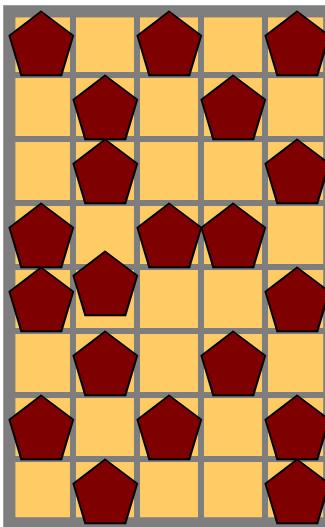
Radioactivity

+

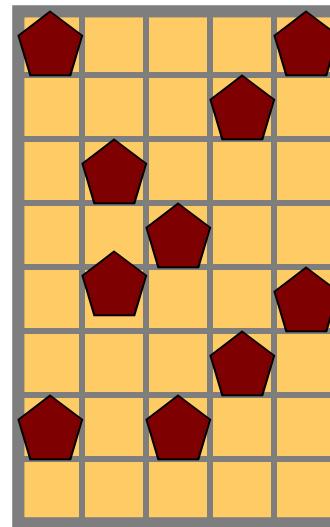
Radioactive Half-Life - the time for $\frac{1}{2}$ of the radioactive atoms to decay



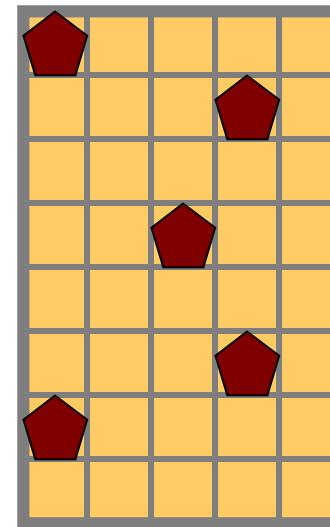
2 PM



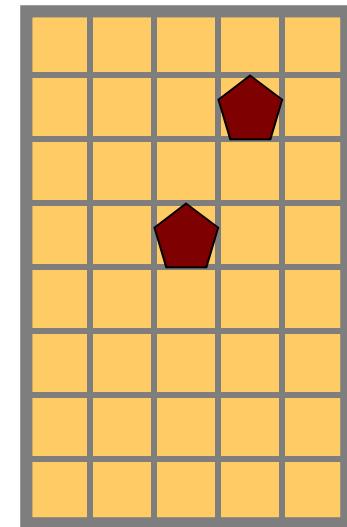
3 PM



4 PM



5 PM



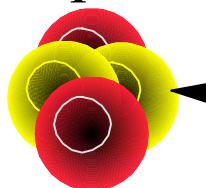
6 PM

- This analogy is the half-life of a box of candy

Radioactivity

- Radioactive Decay
- Ionizing Radiation
(Interaction with Matter)

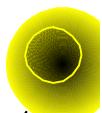
Alpha



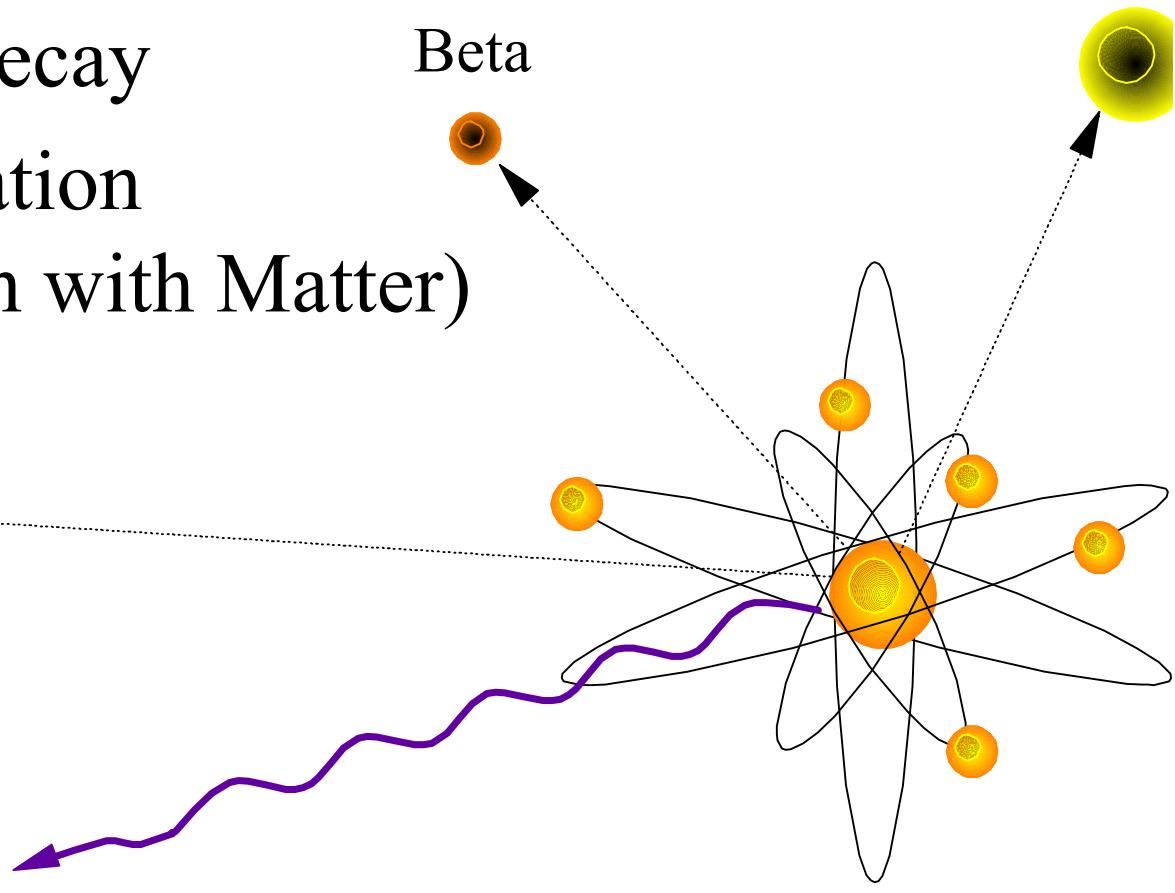
Beta



Neutron

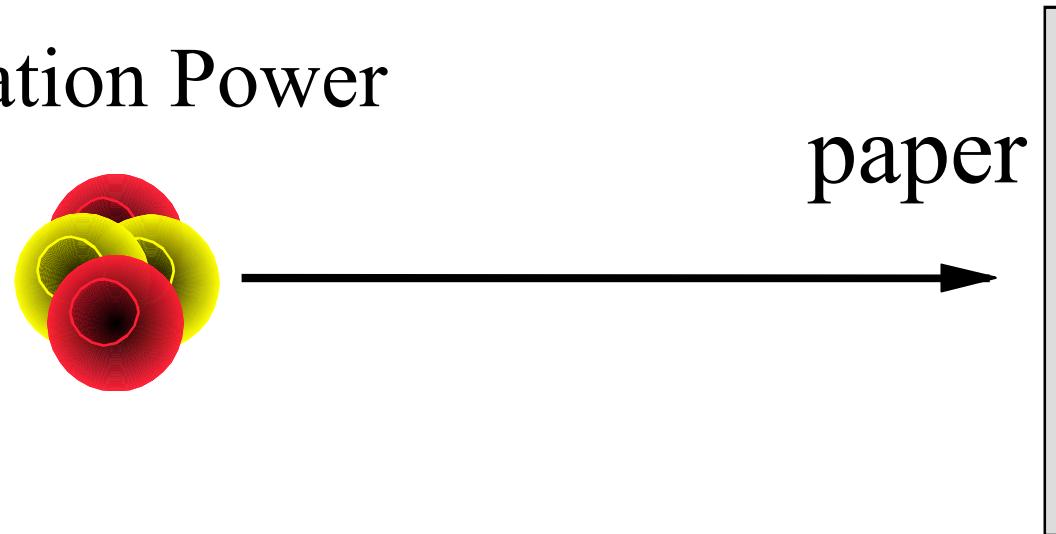


Gamma



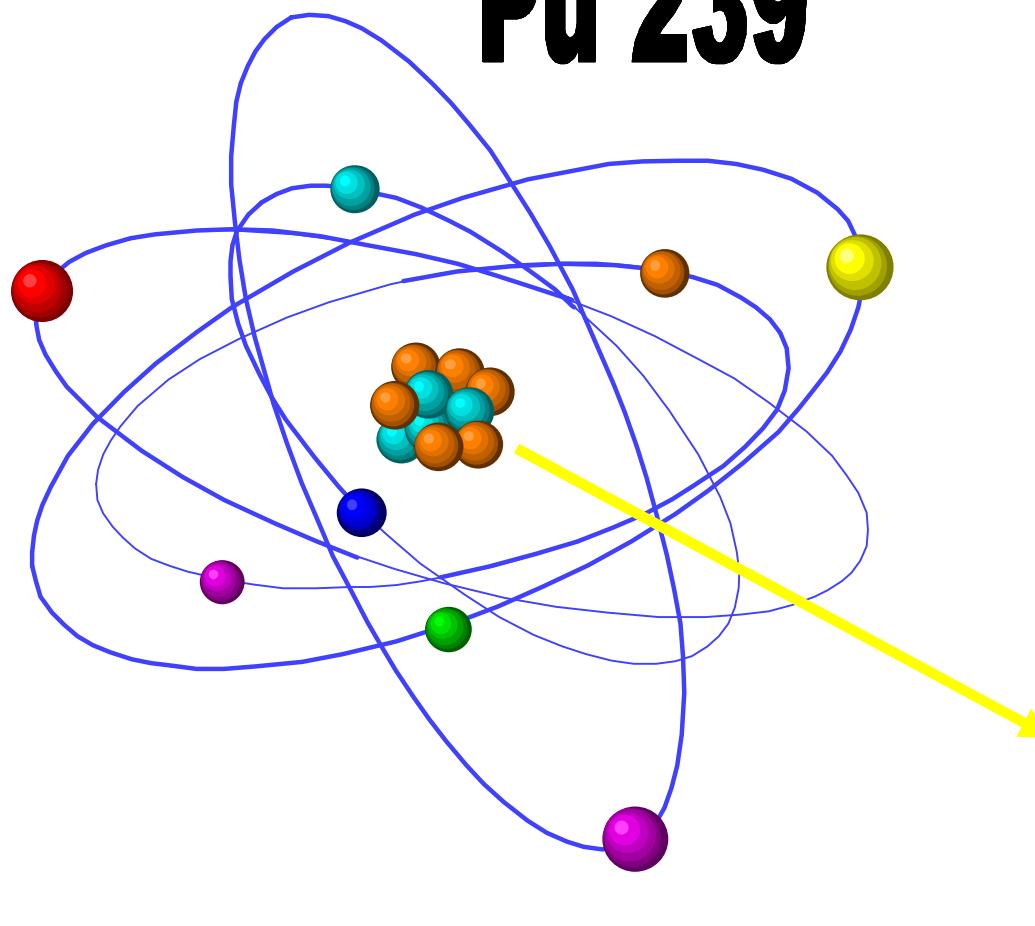
Alpha Particles

- Heavy – Positively Charged
- Identical to a Helium atom
- Strong Interaction with Matter (Heavily Ionizing)
- Weak Penetration Power



Alpha Particles (continued)

Pu 239

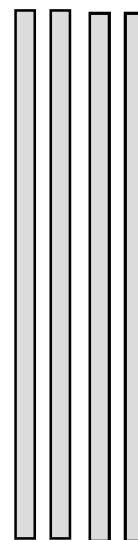


**ALPHA
PARTICLE**

Always accompanied by X-ray or
gamma radiation!

Beta Particles

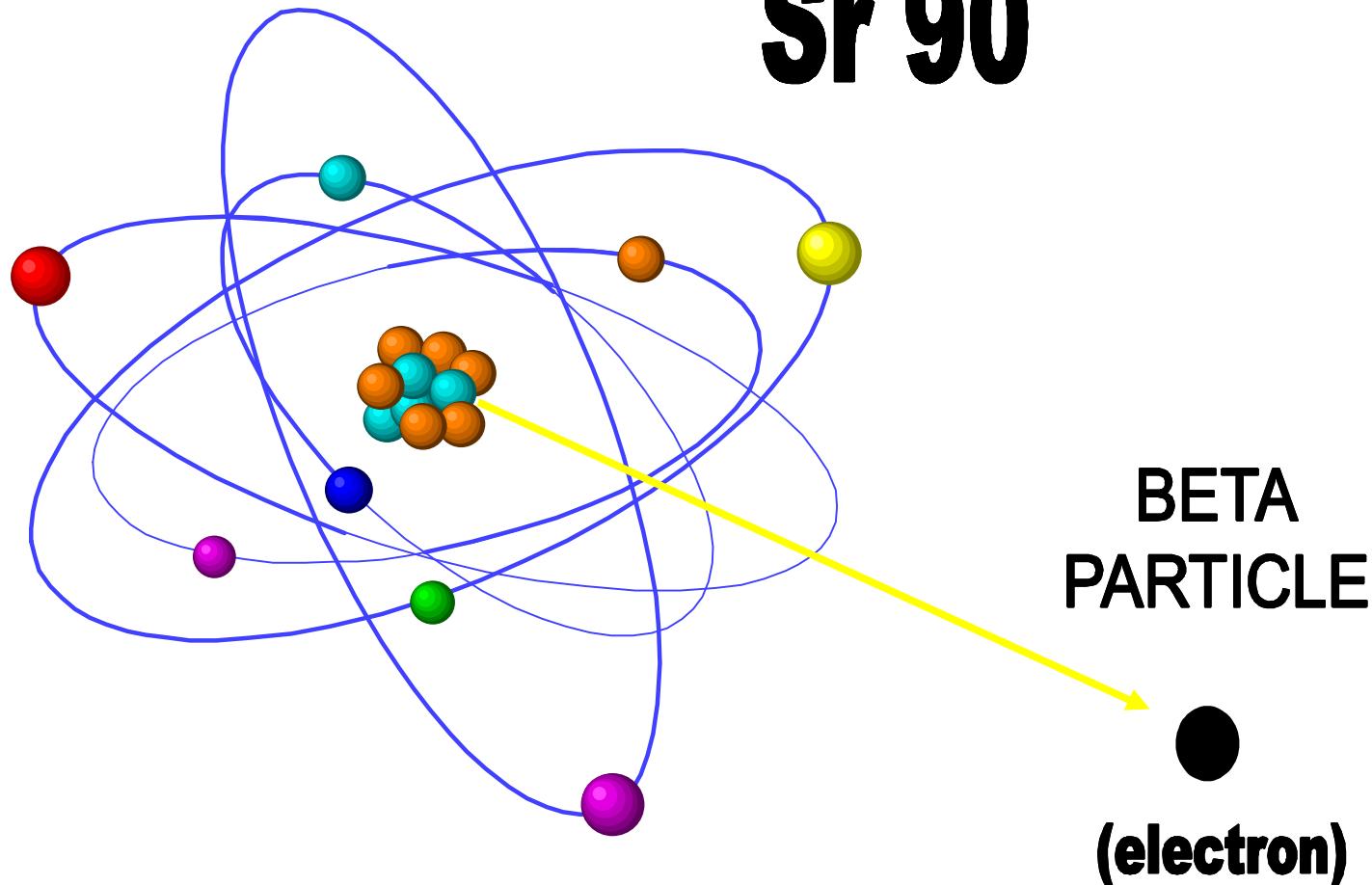
- Light – Negatively Charged; an electron
- Weak Interaction with Matter (Lightly Ionizing)
- Moderate Penetration Power



papers,
plastics
aluminum

Beta Particles (continued)

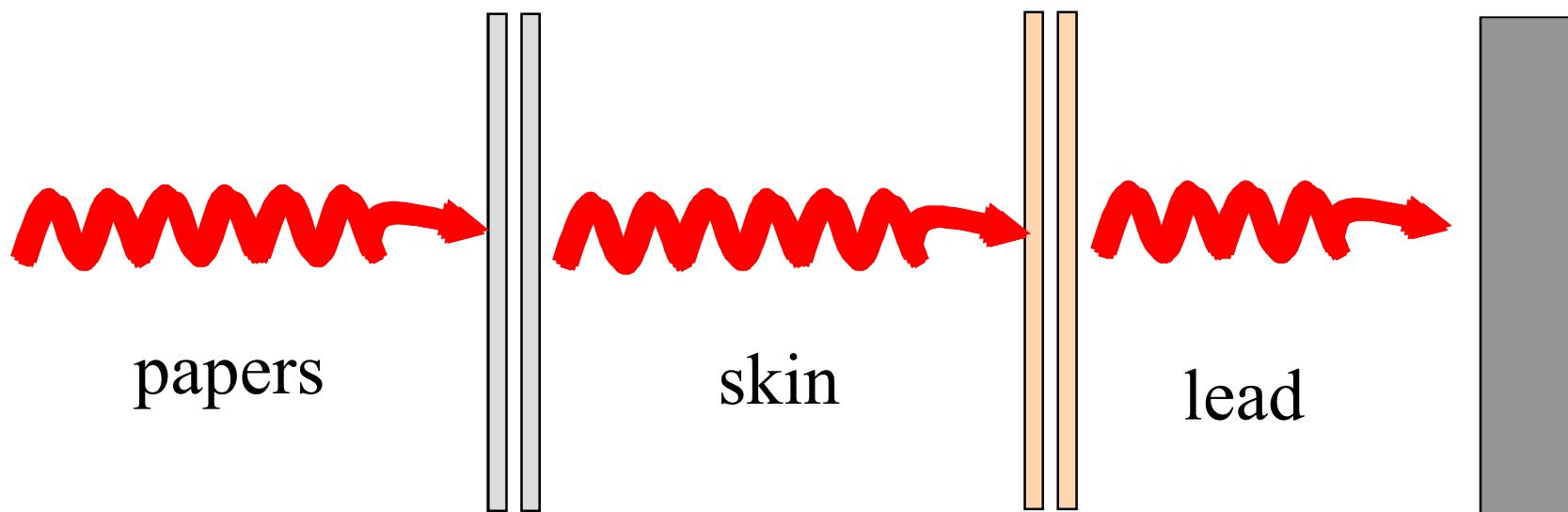
Sr 90



Accompanied by X-ray or gamma
radiation (6 exceptions)

Gamma Rays

- No Mass - No Charge; high energy electromagnetic waves
- Weak Interaction with Matter (Lightly Ionizing)
- Strong Penetration Power



Neutrons

- Heavy - No Charge
- Moderate Interaction with Matter (Moderately Ionizing)
- Strong Penetration Power

