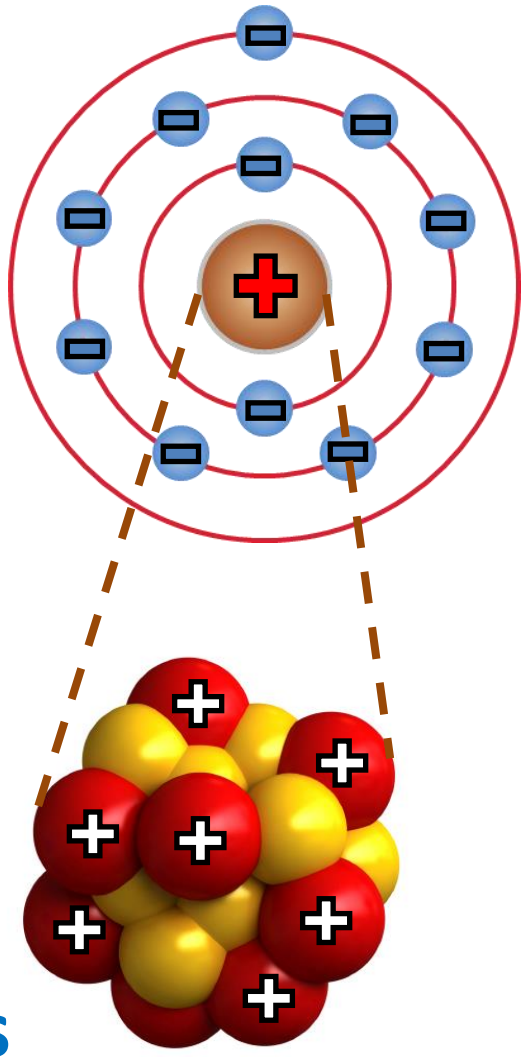
Atomic Structure Summary

- **All atoms have:**
  - a positively charged nucleus
  - and negatively charged electrons moving around within atomic orbitals
- **Atomic nucleus consists of:**
  - positively charged protons
  - and neutrons that have no electric charge
- **Atoms are neutral:**

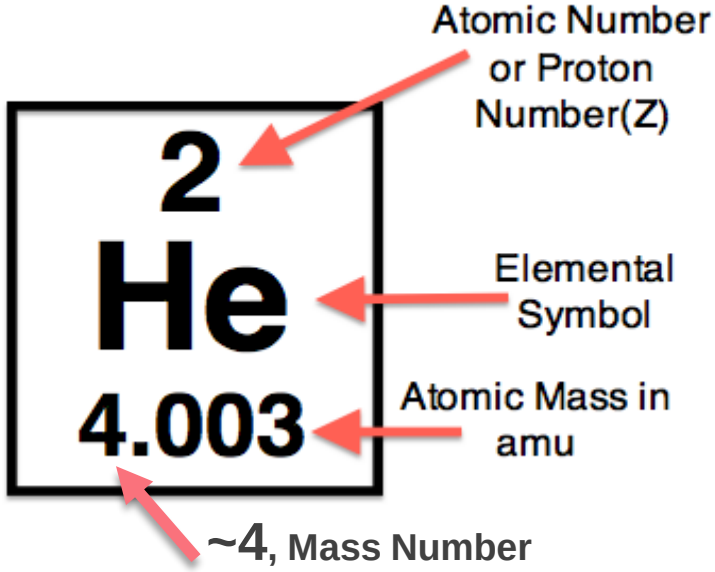
  # of protons = # of electrons



Understanding Elements

The number of protons and neutrons in the nucleus give the atoms their specific characteristics.

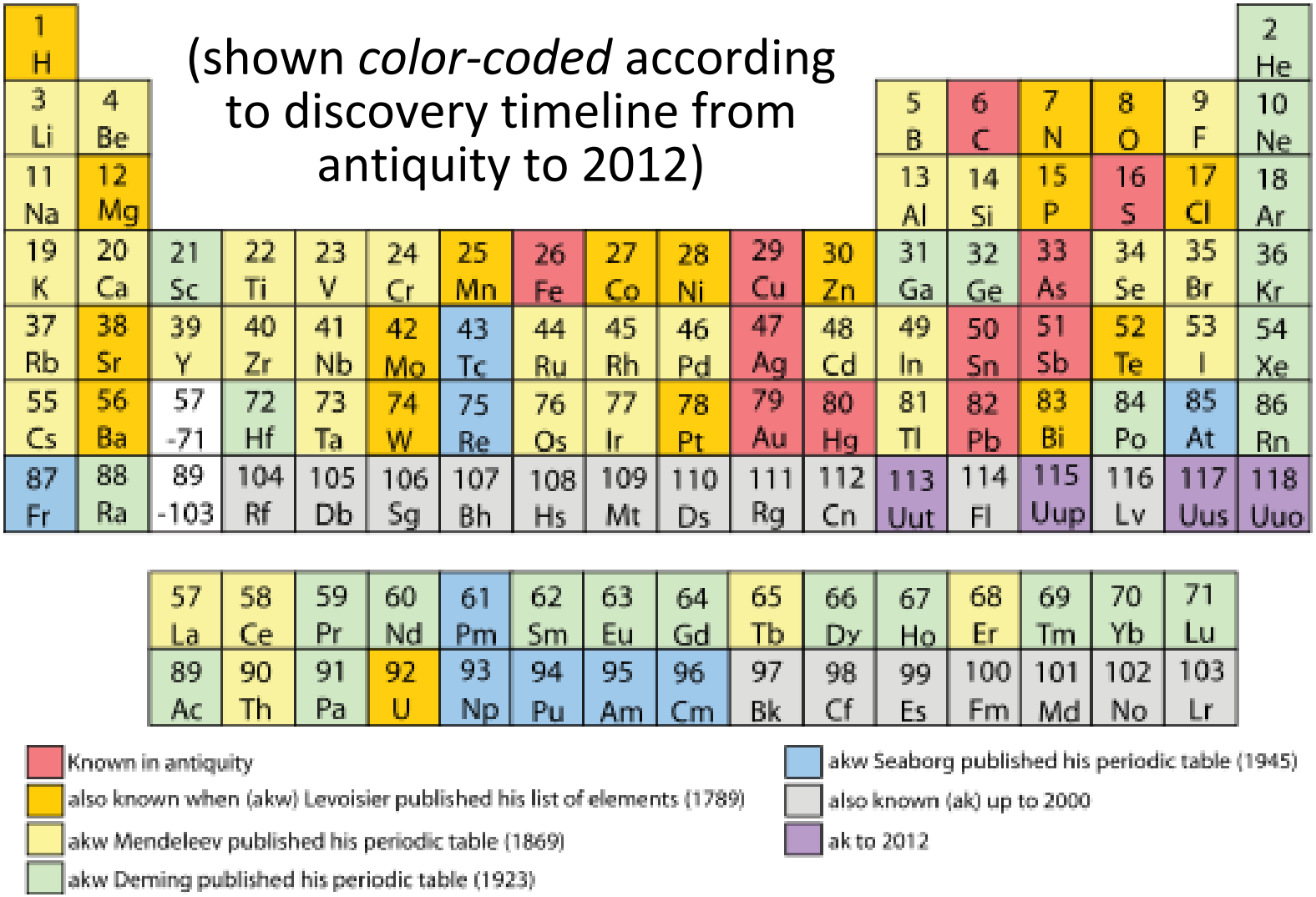
- **All atoms of the same chemical element contain the same number of protons, defined by a unique atomic number of that element.**
- **For example, all helium atoms, and only helium atoms, contain two protons and have an atomic number of 2.**



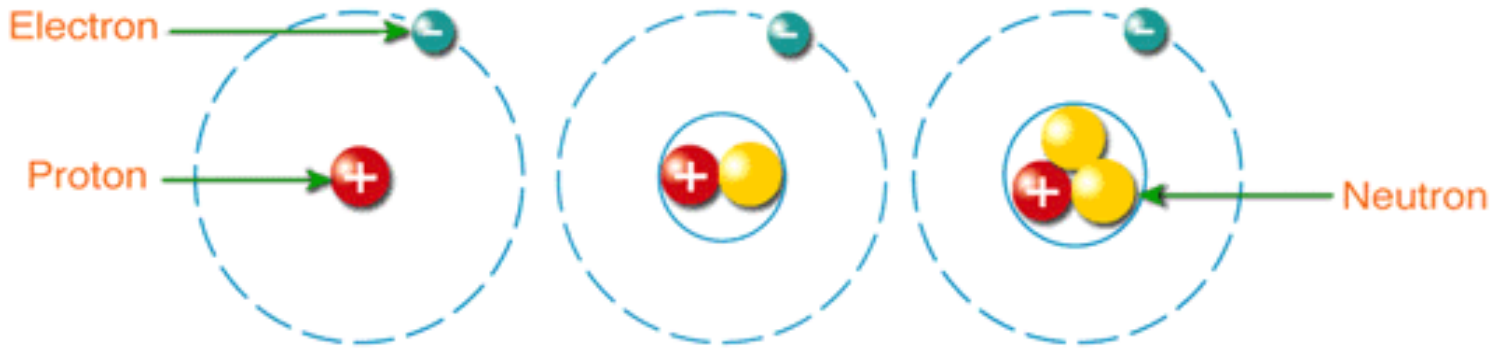
- **Atoms are also characterized by:**
  - **atomic mass, "relative isotopic mass" in *unified atomic mass units*, which is roughly (within 1%) equal to the whole mass number (since the mass of a proton and the mass of a neutron are almost the same and the mass of the atom's electrons is negligibly small)**
  - **mass number, which is a sum of the number of protons and the number of neutrons in the nucleus (number of *nucleons*)**

Periodic Table of Elements

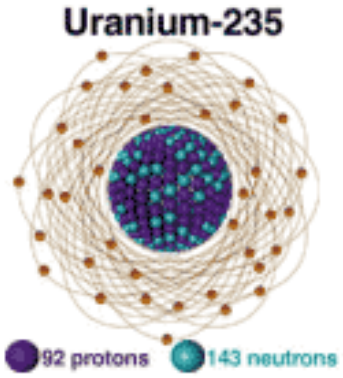
is arranged in order of increasing atomic number



Isotopes are different <u>forms of a given element</u>
that have the same number of ***protons***
in each atom but differ in number of ***neutrons***.



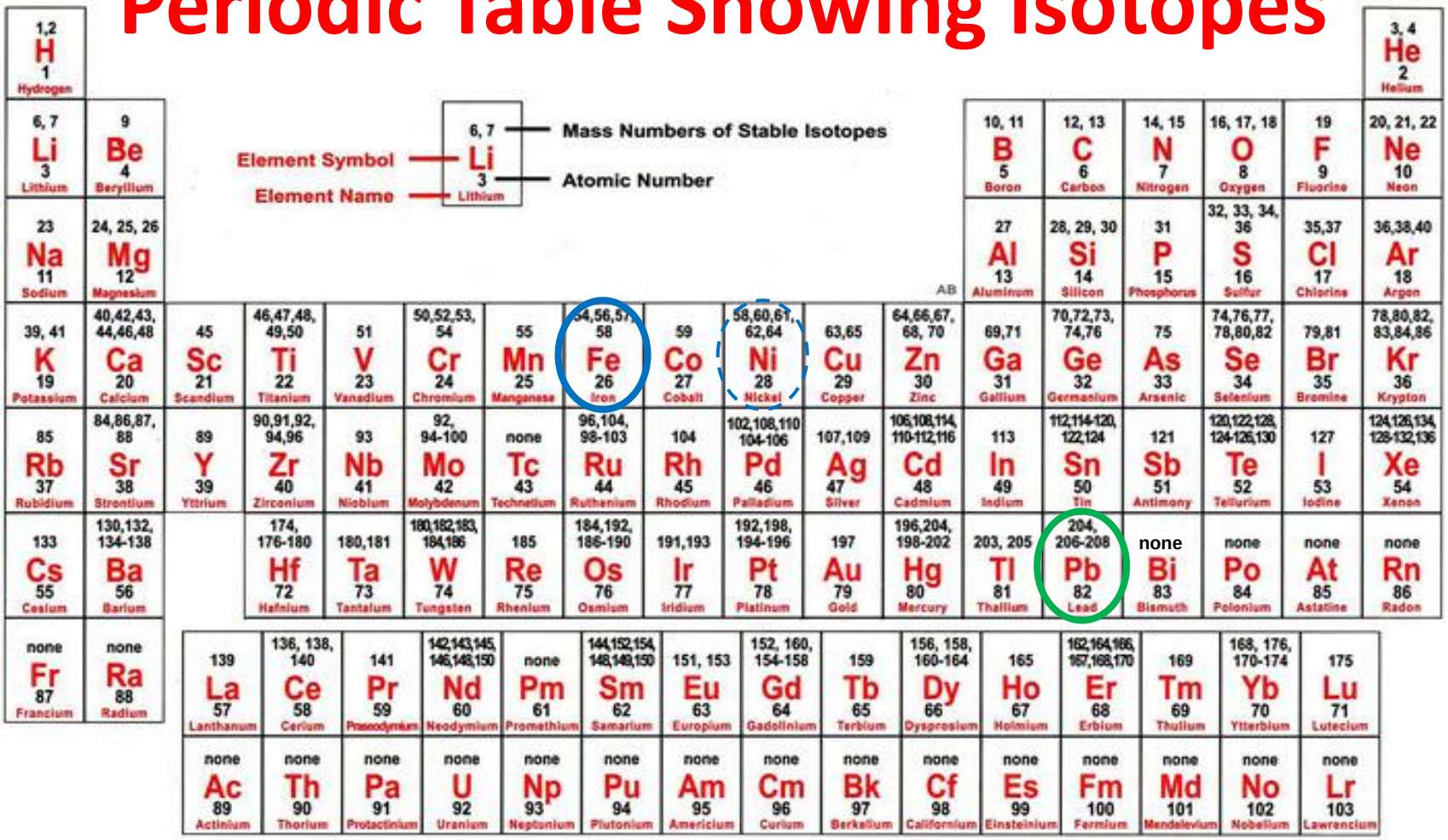
Most elements have more than one isotope.



There are 20 Plutonium isotopes, all of them *unstable*!

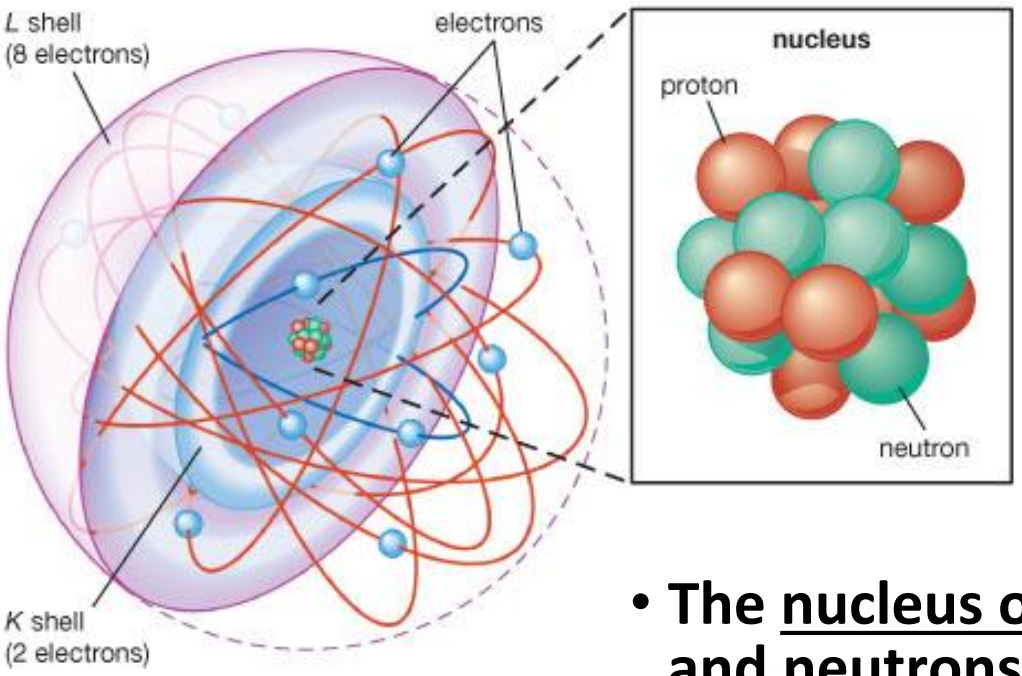
Pu^{228} ⟹ Pu^{247}

Periodic Table Showing Isotopes



- **The nucleus of an iron isotope with mass number 56 is more stable than any other element's nucleus (the farther from 56 an element's mass number is, the more unstable that element's nucleus tends to be).**
- **The heaviest element that still has stable isotopes is Lead.**

What Holds an Atom Together?

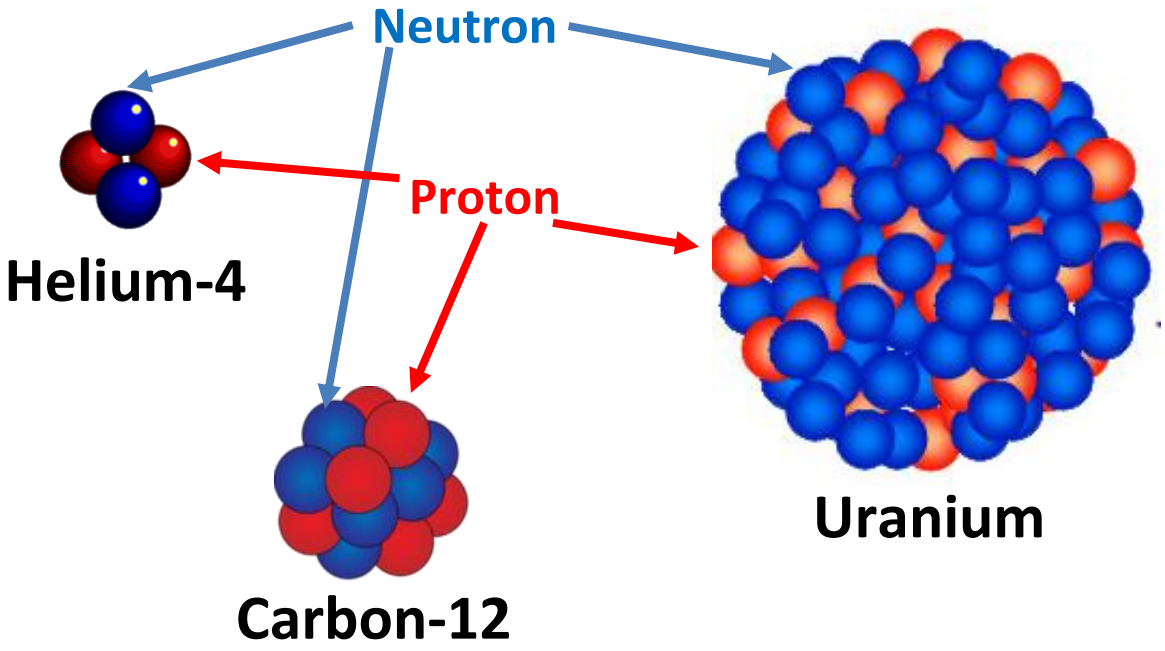


- **The <u>electrons</u> are kept in orbit around the nucleus due to an <u>electromagnetic field</u> of attraction between the positive (+) charge of the protons and the negative (-) charge of the electrons.**

- **The <u>nucleus of protons and neutrons</u> is kept together by the <u>nuclear (strong) force</u>, which *opposes and overcomes the electromagnetic repulsion when particles are very close to each other (~1 fm!)*.**

Binding Energy and Atom Stability

Nuclear (binding) energy is the energy associated with the **nuclear force.**



- An ***unstable atom*** does not have enough binding energy to hold the nucleus together permanently and ***will lose neutrons and/or protons*** as it attempts to become stable…

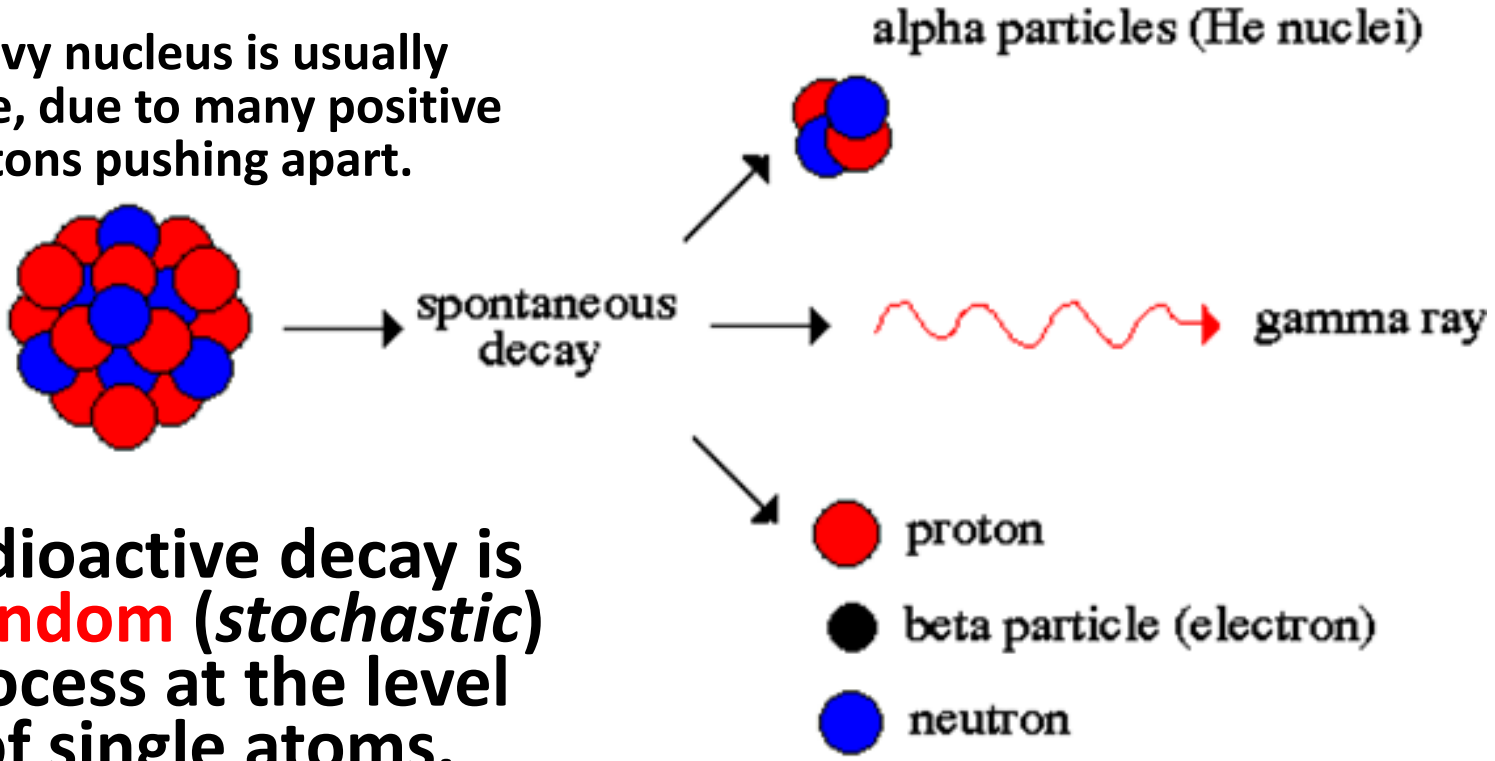
…radioactivity!

- A stable atom is an atom that has enough binding energy to hold the nucleus together permanently.

Radioactive Decay

Radioactive decay, also known as radioactivity or nuclear decay, is the process by which a nucleus of an unstable atom loses energy by emitting ionizing radiation: ^4He (alpha particles), β particles (electrons), γ rays (energetic photons), neutrons.

A heavy nucleus is usually unstable, due to many positive protons pushing apart.



Radioactive decay is a random (*stochastic*) process at the level of single atoms.

Half-Life of Radioactive Isotope

The decay rate of a radioactive isotope is characterized by its half-life: the *time it takes for one-half of the atoms* of a radioactive material *to disintegrate*.

Radioisotope	Half-life
Polonium-215	0.0018 seconds
Bismuth-212	60.5 seconds
Sodium-24	15 hours
Iodine-131	8.07 days
Cobalt-60	5.26 years
Radium-226	1600 years
Uranium-238	4.5 billion years

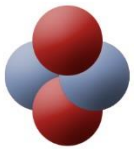
Ionizing Radiation

<u>Ionizing radiation</u> can pose a serious health threat to humans: it is capable of changing the basic makeup of atoms and molecules in cells, and more specifically the DNA molecules inside of cells.

Alpha Particle

LARGE PARTICLE, TRAVELS A FEW INCHES

STOPPED BY A SHEET OF PAPER



- interacts strongly with matter
- unable to penetrate the outer layer of dead skin cells
- capable of causing serious cell damage if an alpha emitting substance is ingested in food or air

Beta Particle

VERY SMALL PARTICLE, TRAVELS A FEW FEET

STOPPED BY WOOD, PLASTIC OR ALUMINUM

- can penetrate skin a few centimeters
- main threat is still primarily from internal emission from ingested material

Neutron

SMALL PARTICLE, TRAVELS A FEW FEET

ENERGY ABSORBED BY WATER AND CONCRETE

- the only type of radiation that is able to turn other materials radioactive

Gamma Ray

HIGH ENERGY, TRAVELS LONG DISTANCES

ENERGY ABSORBED BY HEAVY METALS AND CONCRETE

- very high energy electromagnetic radiation
- cause diffuse damage throughout the body (“radiation sickness”)