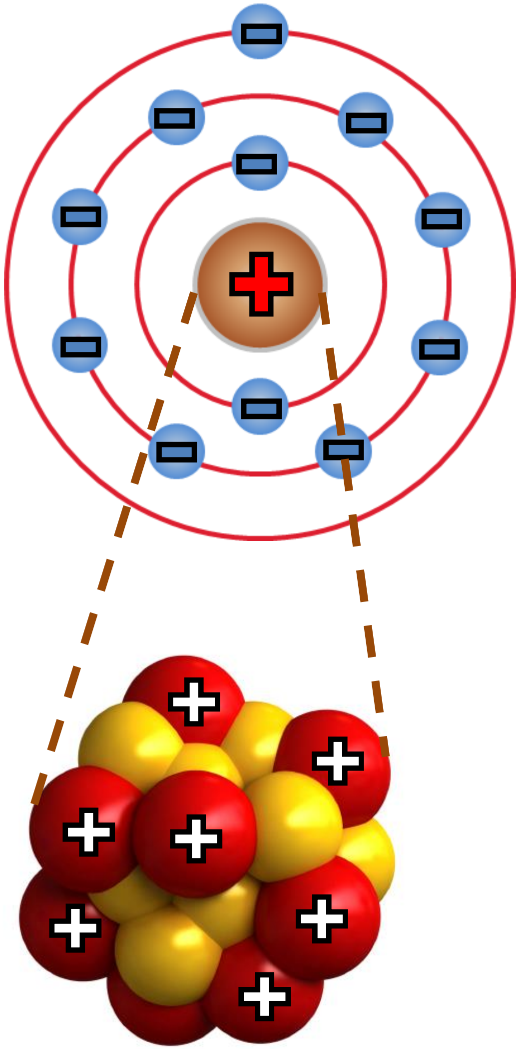
Atomic Structure Summary

- <u>All atoms</u> have:
  - a positively charged nucleus
  - and negatively charged electrons moving around within atomic orbitals

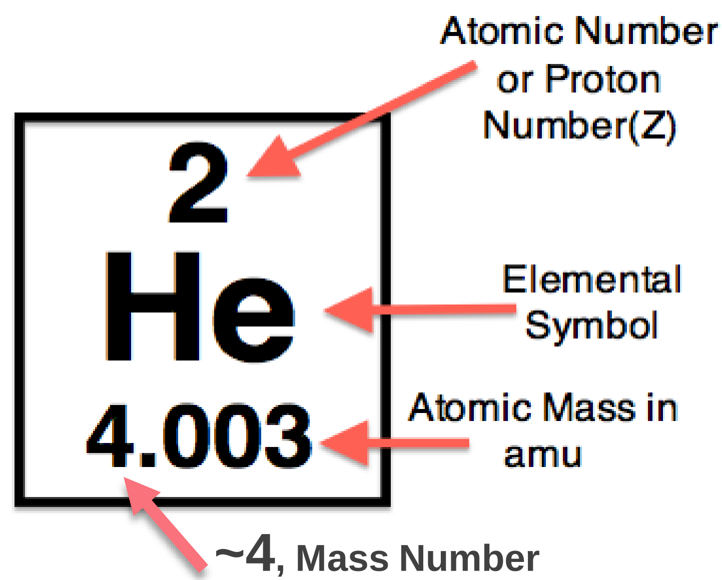
- Atomic nucleus consists of:
  - positively charged protons
  - and neutrons that have no electric charge



Understanding Elements

The <u>number of protons and neutrons</u> in the nucleus give the atoms their <u>specific characteristics</u>.

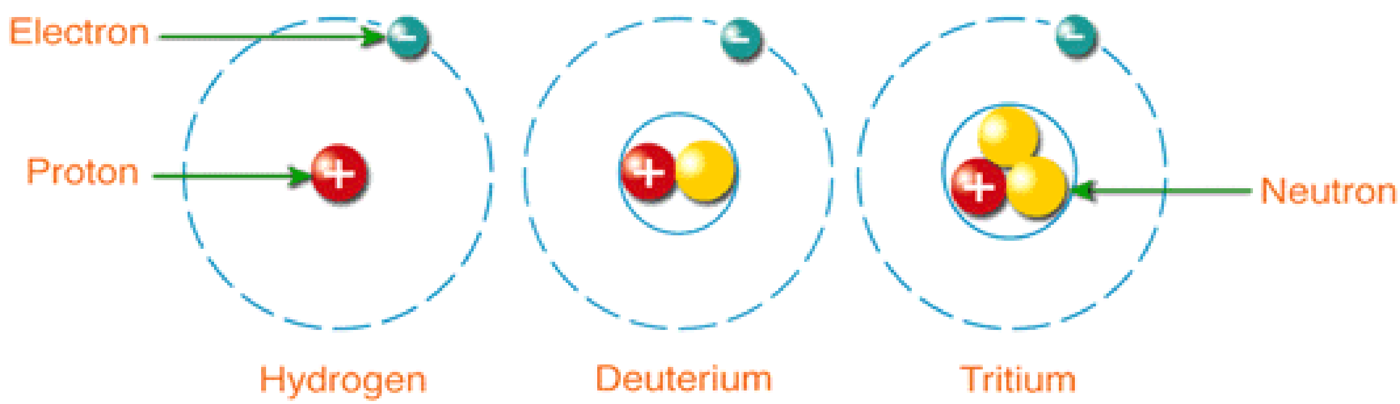
- **All atoms of the same chemical element contain the same number of protons, defined by a unique atomic number of that element.**
- **For example, all <u>helium</u> atoms, and only helium atoms, contain two protons and have an <u>atomic number of 2</u>.**



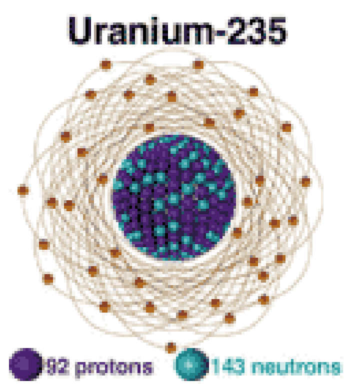
- **Atoms are also characterized by:**
  - ➢ **atomic mass, "relative isotopic mass" in *unified atomic mass units*, which is roughly (within 1%) equal to the whole mass number (since the mass of a proton and the mass of a neutron are almost the same and the mass of the atom's electrons is negligibly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

What is Isotope?

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



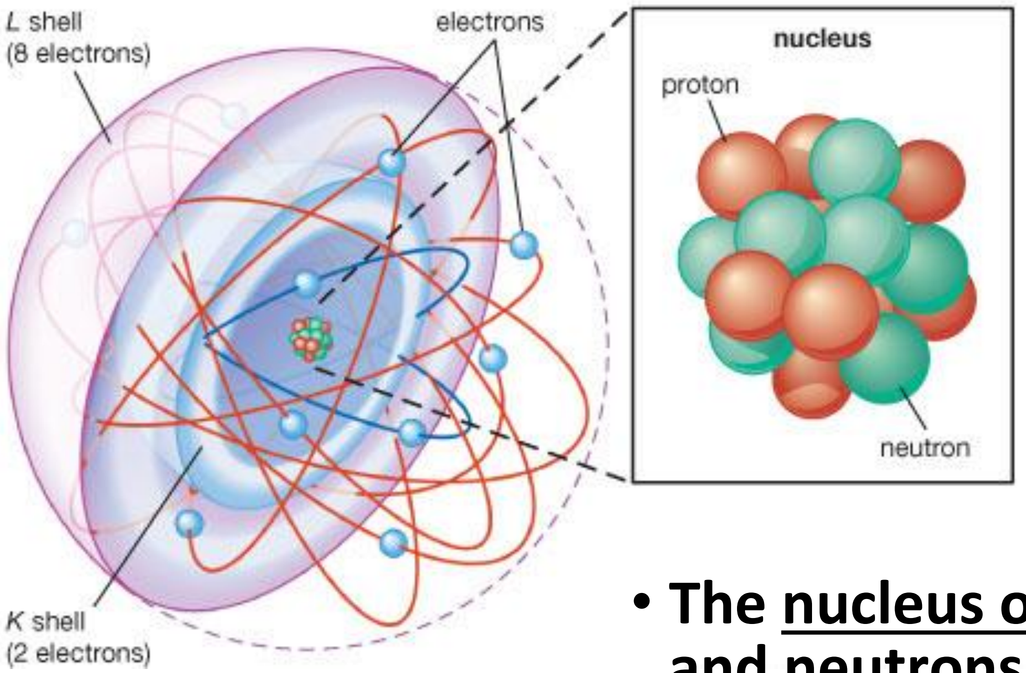
Most elements have more than one isotope.



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

Pu^{228} → Pu^{247}

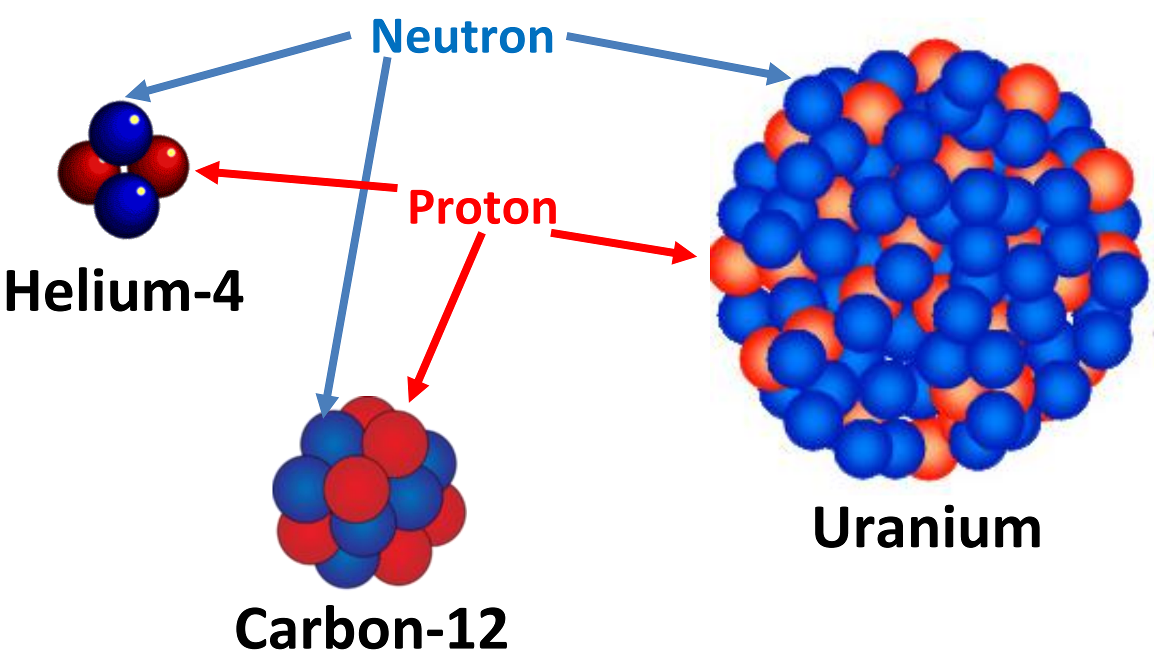
What Holds an Atom Together?



- **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.**

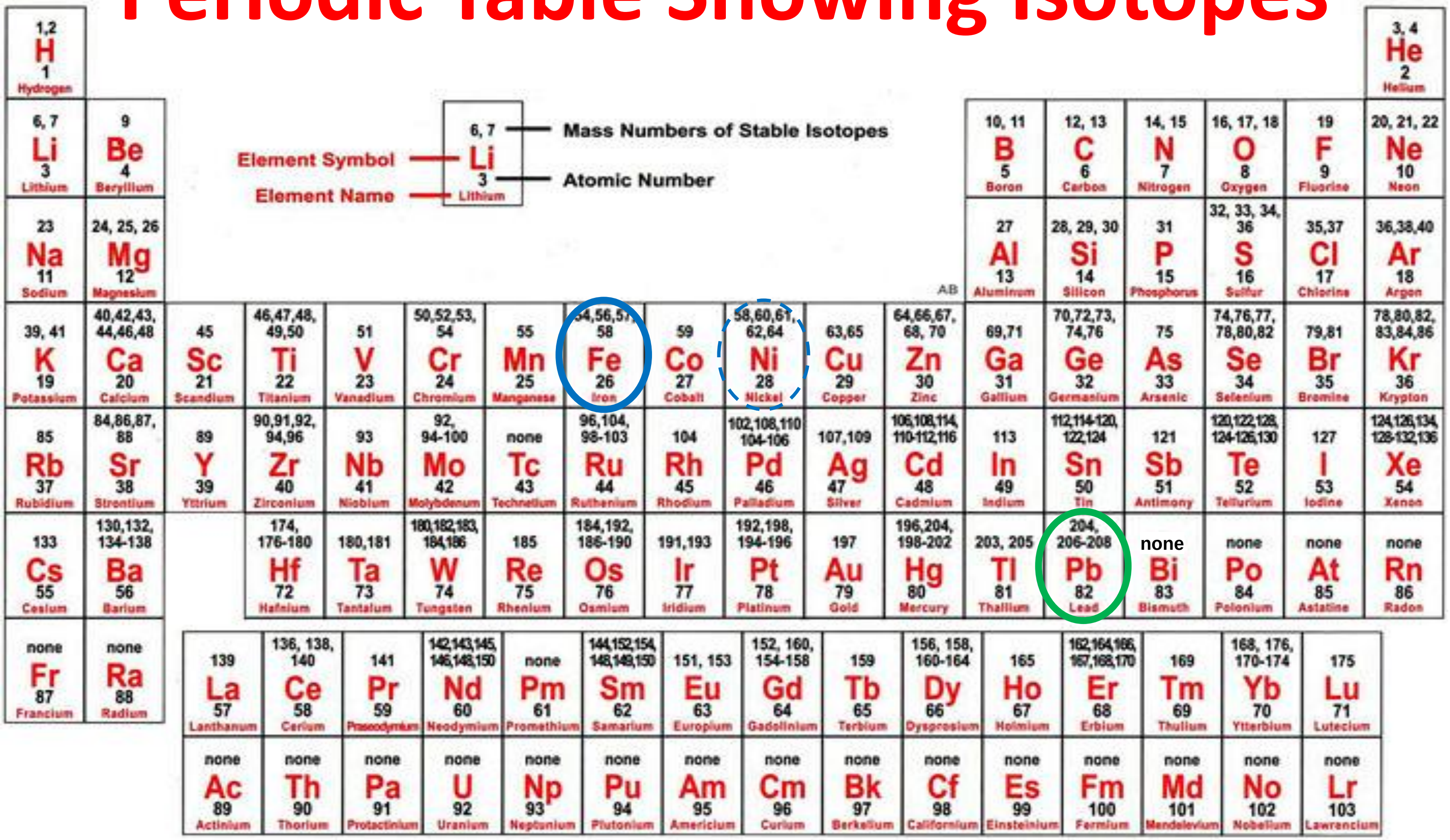


- An ***unstable atom*** does not have enough binding energy to hold the nucleus together permanently and ***will lose neutrons and/or protons*** as it attempts to become stable…

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

…radioactivity!

Periodic Table Showing Isotopes

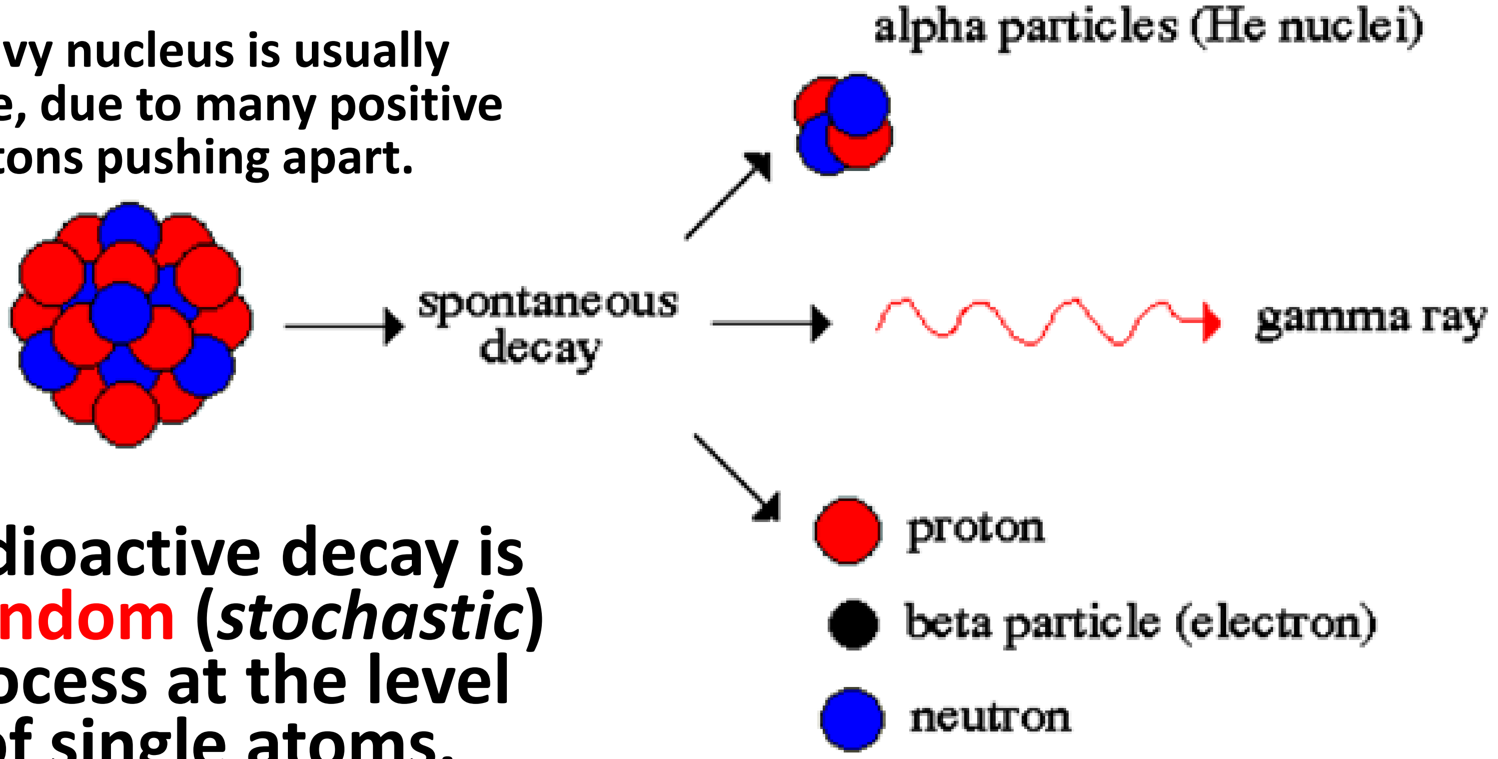


- The nucleus of an **iron isotope with mass number 56** is more stable than any other element's nucleus (the farther from 56 an element's mass number is, the more unstable that element's nucleus tends to be).
- The heaviest element that still has stable isotopes is **Lead**.

Radioactive Decay

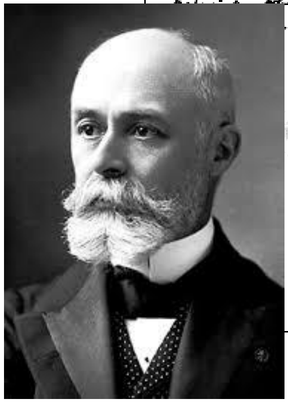
<u>**Radioactive decay**</u>, also known as <u>radioactivity</u> or <u>nuclear decay</u>, is the process by which **a nucleus of an unstable atom loses energy by emitting ionizing radiation**: ^{4}He (alpha particles), β particles (electrons), γ rays (energetic photons), neutrons.

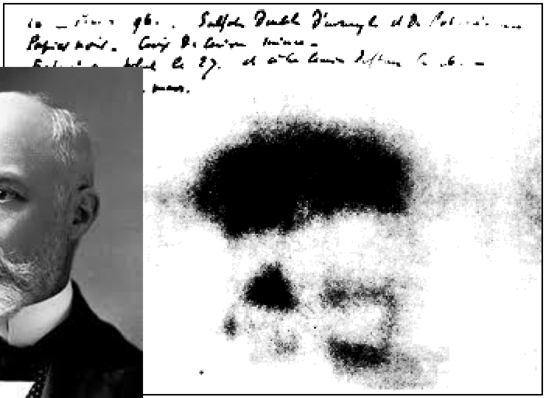
A heavy nucleus is usually unstable, due to many positive protons pushing apart.



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

Discovery of Radioactivity





- <u>Henri Becquerel, 1896</u>:

  - radioactivity was first discovered in uranium salts during his work on phosphorescence.

- <u>Marie Sklodowska-Curie and Pierre Curie, 1898</u>:

  - conducted a systematic study to determine which other elements and compounds emitted “mysterious radiation” that they called “radioactivity”,

  - isolated a new radioactive element, <u>*polonium*</u> (named in honor of Marie's home country),

  - four years later, discovered an even more intensely radioactive substance, which they called <u>*radium*</u>.

- <u>Ernest Rutherford and Frederick Soddy, 1899-1903</u>:

  - discovered three different types of radiation "rays" with very different powers of penetration, introduced the term “half-life”, and proposed that <u>atoms were not conserved</u> in radioactive emissions.

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