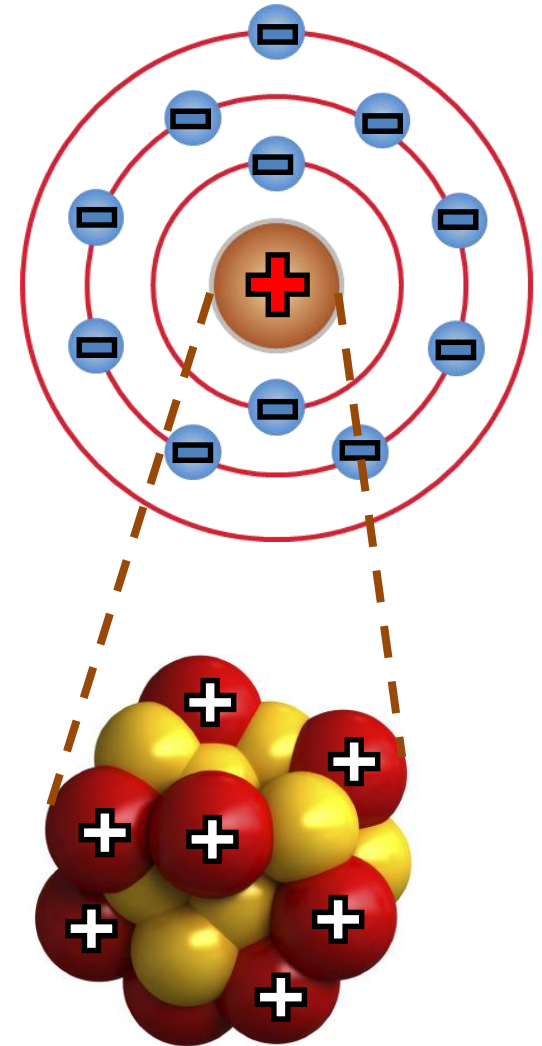


# Nuclear Reactions

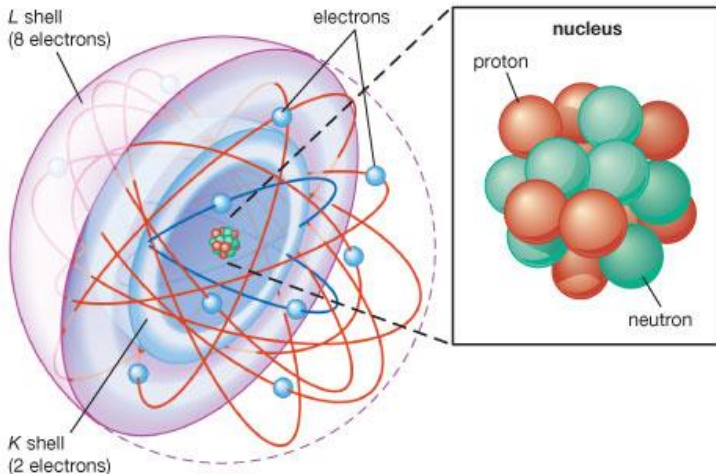
## Part 1

# Atomic Structure Summary

- All atoms have:
  - a positively charged **nucleus**
  - and negatively charged **electrons** around it
  
- Atomic **nucleus** consists of:
  - positively charged **protons**
  - and **neutrons** that have no electric charge



# Forces Inside the Atom

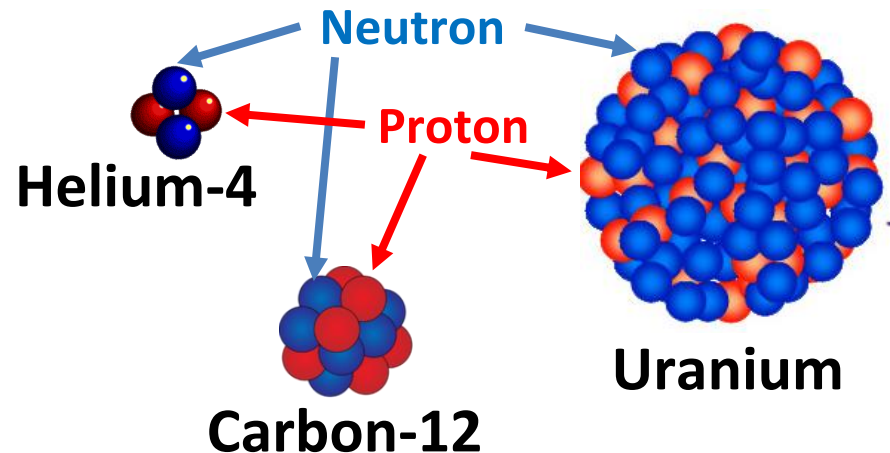


## What holds an atom together?

- The electrons are kept in orbit around the nucleus due to an electromagnetic field of attraction between the positive charge of the protons and the negative charge of the electrons.
- The nucleus of protons and neutrons is kept together by the nuclear (strong) force, which *opposes and overcomes the electromagnetic repulsion when particles are very close to each other (~1 fm!)*.

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

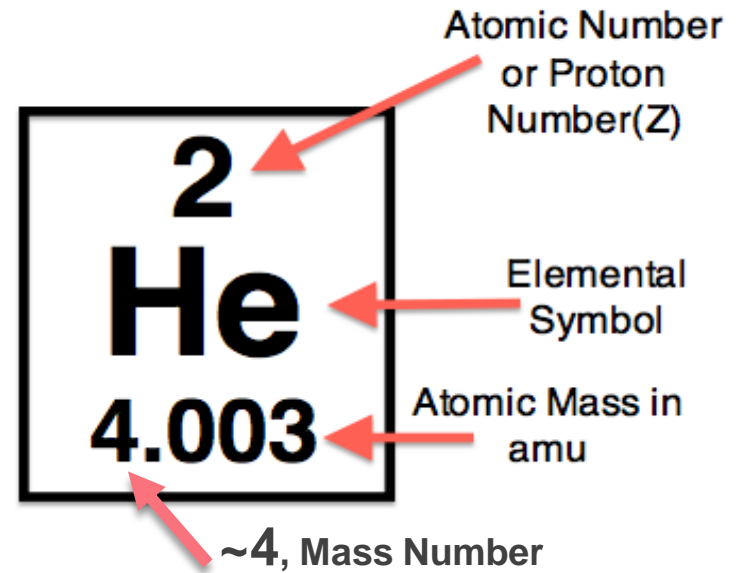
- A stable atom is an atom that has enough binding energy to hold the nucleus together permanently.
- An unstable atom does not have enough binding energy to hold the nucleus together permanently and will lose neutrons and/or protons as it attempts to become stable.



# Understanding Elements

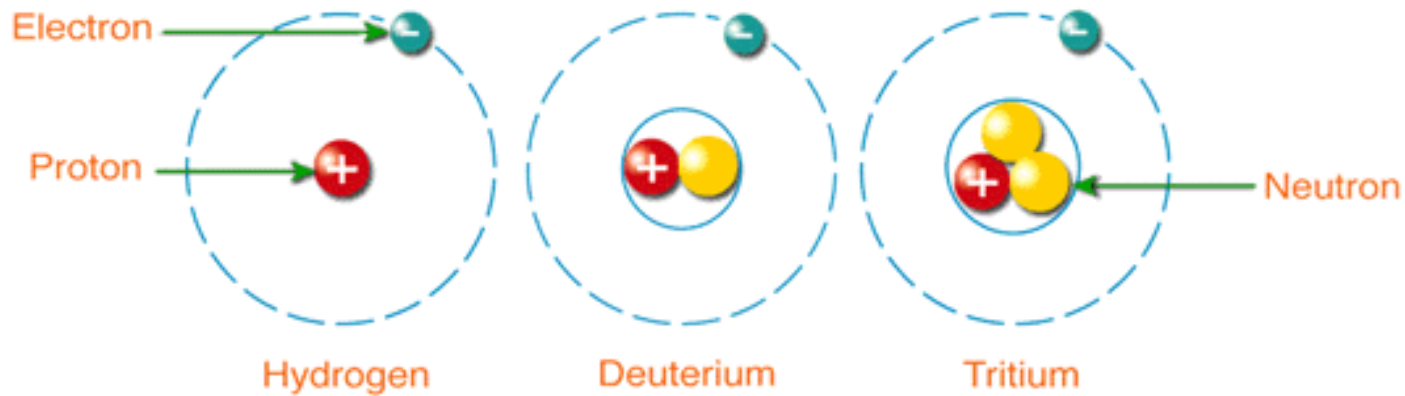
The number of protons and neutrons in the nucleus give the atoms their specific characteristics.

- 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:
  - **mass number**, which is a **sum of the number of protons and the number of neutrons in the nucleus** (number of *nucleons*)
  - **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)

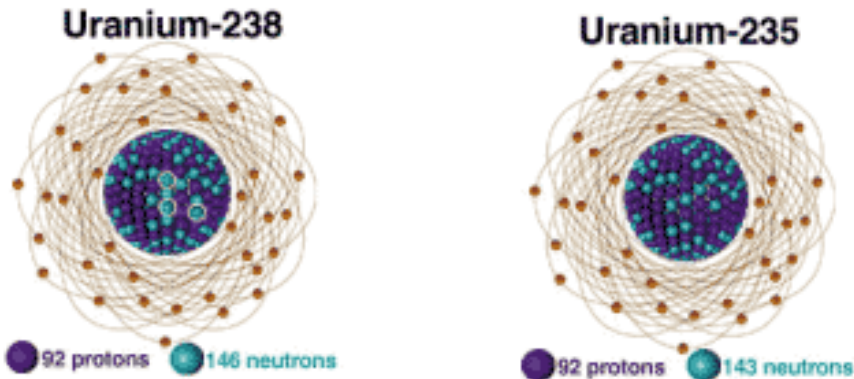


# What is Isotope?

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!**



# Periodic Table Showing Isotopes

1,2 <b>H</b> 1 Hydrogen																	3, 4 <b>He</b> 2 Helium						
6, 7 <b>Li</b> 3 Lithium	9 <b>Be</b> 4 Beryllium	<div style="display: flex; align-items: center; gap: 10px;"> <div style="border: 1px solid black; padding: 5px;">             6, 7 <b>Li</b> 3 Lithium           </div> <div> <p>Mass Numbers of Stable Isotopes →</p> <p>Atomic Number →</p> <p>Element Symbol →</p> <p>Element Name →</p> </div> </div>																10, 11 <b>B</b> 5 Boron	12, 13 <b>C</b> 6 Carbon	14, 15 <b>N</b> 7 Nitrogen	16, 17, 18 <b>O</b> 8 Oxygen	19 <b>F</b> 9 Fluorine	20, 21, 22 <b>Ne</b> 10 Neon
23 <b>Na</b> 11 Sodium	24, 25, 26 <b>Mg</b> 12 Magnesium	AB																27 <b>Al</b> 13 Aluminum	28, 29, 30 <b>Si</b> 14 Silicon	31 <b>P</b> 15 Phosphorus	32, 33, 34, 36 <b>S</b> 16 Sulfur	35, 37 <b>Cl</b> 17 Chlorine	36, 38, 40 <b>Ar</b> 18 Argon
39, 41 <b>K</b> 19 Potassium	40, 42, 43, 44, 46, 48 <b>Ca</b> 20 Calcium	45 <b>Sc</b> 21 Scandium	46, 47, 48, 49, 50 <b>Ti</b> 22 Titanium	51 <b>V</b> 23 Vanadium	50, 52, 53, 54 <b>Cr</b> 24 Chromium	55 <b>Mn</b> 25 Manganese	54, 56, 57, 58 <b>Fe</b> 26 Iron	59 <b>Co</b> 27 Cobalt	58, 60, 61, 62, 64 <b>Ni</b> 28 Nickel	63, 65 <b>Cu</b> 29 Copper	64, 66, 67, 68, 70 <b>Zn</b> 30 Zinc	69, 71 <b>Ga</b> 31 Gallium	70, 72, 73, 74, 76 <b>Ge</b> 32 Germanium	75 <b>As</b> 33 Arsenic	74, 76, 77, 78, 80, 82 <b>Se</b> 34 Selenium	79, 81 <b>Br</b> 35 Bromine	78, 80, 82, 83, 84, 86 <b>Kr</b> 36 Krypton						
85 <b>Rb</b> 37 Rubidium	84, 86, 87, 88 <b>Sr</b> 38 Strontium	89 <b>Y</b> 39 Yttrium	90, 91, 92, 94, 96 <b>Zr</b> 40 Zirconium	93 <b>Nb</b> 41 Niobium	92, 94-100 <b>Mo</b> 42 Molybdenum	none <b>Tc</b> 43 Technetium	96, 104, 98-103 <b>Ru</b> 44 Ruthenium	104 <b>Rh</b> 45 Rhodium	102, 108, 110, 104-106 <b>Pd</b> 46 Palladium	107, 109 <b>Ag</b> 47 Silver	106, 108, 114, 110-112, 116 <b>Cd</b> 48 Cadmium	113 <b>In</b> 49 Indium	112, 114-120, 122, 124 <b>Sn</b> 50 Tin	121 <b>Sb</b> 51 Antimony	120, 122, 128, 124-126, 130 <b>Te</b> 52 Tellurium	127 <b>I</b> 53 Iodine	124, 126, 134, 128-132, 136 <b>Xe</b> 54 Xenon						
133 <b>Cs</b> 55 Cesium	130, 132, 134-138 <b>Ba</b> 56 Barium		174, 176-180 <b>Hf</b> 72 Hafnium	180, 181 <b>Ta</b> 73 Tantalum	180, 182, 183, 184, 186 <b>W</b> 74 Tungsten	185 <b>Re</b> 75 Rhenium	184, 192, 186-190 <b>Os</b> 76 Osmium	191, 193 <b>Ir</b> 77 Iridium	192, 198, 194-196 <b>Pt</b> 78 Platinum	197 <b>Au</b> 79 Gold	196, 204, 198-202 <b>Hg</b> 80 Mercury	203, 205 <b>Tl</b> 81 Thallium	204, 206-208 <b>Pb</b> 82 Lead	none <b>Bi</b> 83 Bismuth	none <b>Po</b> 84 Polonium	none <b>At</b> 85 Astatine	none <b>Rn</b> 86 Radon						
none <b>Fr</b> 87 Francium	none <b>Ra</b> 88 Radium	139 <b>La</b> 57 Lanthanum	136, 138, 140 <b>Ce</b> 58 Cerium	141 <b>Pr</b> 59 Praseodymium	142, 143, 145, 146, 148, 150 <b>Nd</b> 60 Neodymium	none <b>Pm</b> 61 Promethium	144, 152, 154, 148, 149, 150 <b>Sm</b> 62 Samarium	151, 153 <b>Eu</b> 63 Europium	152, 160, 154-158 <b>Gd</b> 64 Gadolinium	159 <b>Tb</b> 65 Terbium	156, 158, 160-164 <b>Dy</b> 66 Dysprosium	165 <b>Ho</b> 67 Holmium	162, 164, 166, 167, 168, 170 <b>Er</b> 68 Erbium	169 <b>Tm</b> 69 Thulium	168, 176, 170-174 <b>Yb</b> 70 Ytterbium	175 <b>Lu</b> 71 Lutetium							
		none <b>Ac</b> 89 Actinium	none <b>Th</b> 90 Thorium	none <b>Pa</b> 91 Protactinium	none <b>U</b> 92 Uranium	none <b>Np</b> 93 Neptunium	none <b>Pu</b> 94 Plutonium	none <b>Am</b> 95 Americium	none <b>Cm</b> 96 Curium	none <b>Bk</b> 97 Berkelium	none <b>Cf</b> 98 Californium	none <b>Es</b> 99 Einsteinium	none <b>Fm</b> 100 Fermium	none <b>Md</b> 101 Mendelevium	none <b>No</b> 102 Nobelium	none <b>Lr</b> 103 Lawrencium							

- 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**.

# Three Types of Nuclear Reactions

- 1. Radioactive decay** – an unstable nucleus spontaneously emits a small particle of radiation to become:
  - a **different isotope** of the **same element** or
  - a **different element** (such process is called *transmutation*).
- 2. Nuclear Fusion** – the joining of two atoms to form a larger one.
- 3. Nuclear Fission** – the splitting of an atom into two smaller atoms.