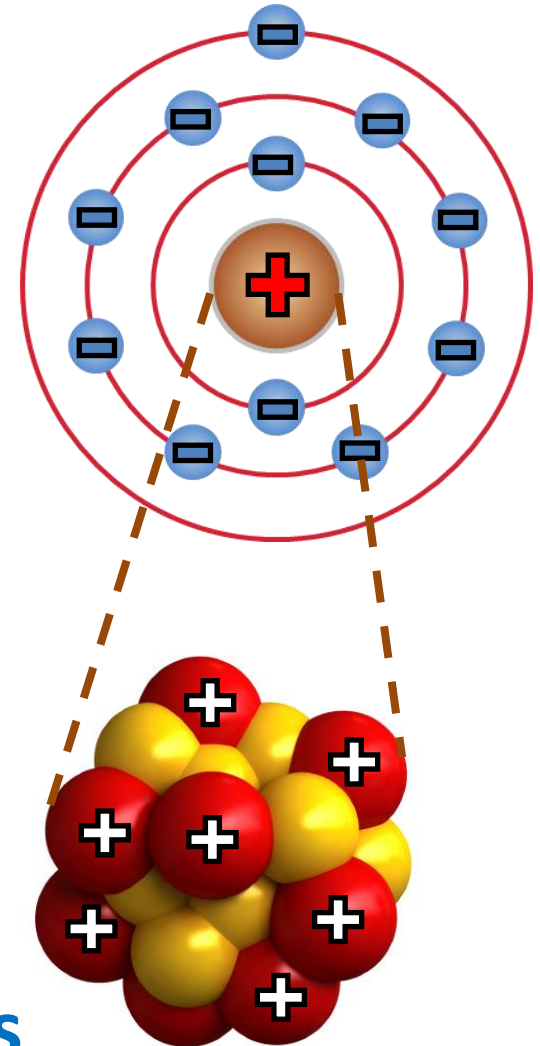


Atomic Structure Summary

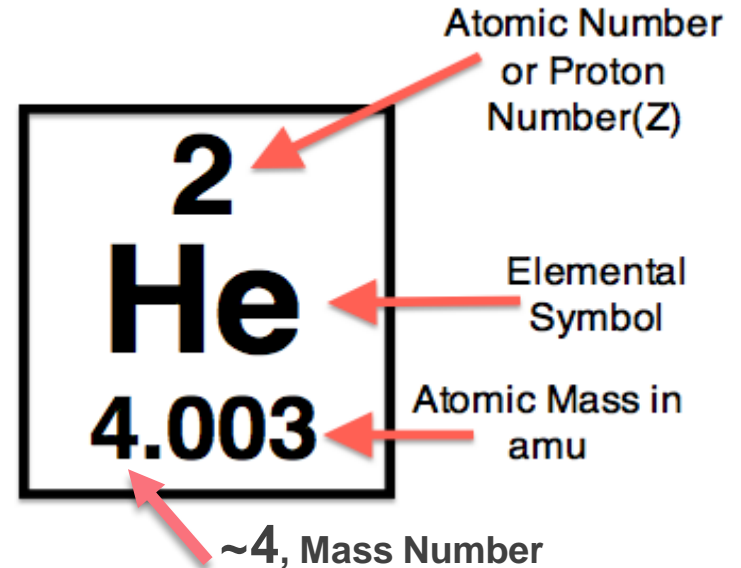
- All atoms have:
 - a positively charged **nucleus**
 - and negatively charged **electrons** moving around within atomic orbitals
- Atomic **nucleus** consists of:
 - positively charged **protons**
 - and **neutrons** that have no electric charge
- Atoms are neutral:
of protons = # of electrons



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

(shown *color-coded* according to discovery timeline from antiquity to 2012)

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
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	-71	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	-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

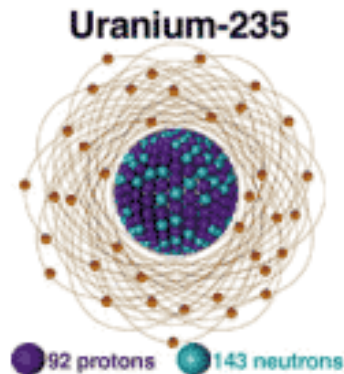
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

- Known in antiquity
- also known when (akw) Levoisier published his list of elements (1789)
- akw Mendeleev published his periodic table (1869)
- akw Deming published his periodic table (1923)
- akw Seaborg published his periodic table (1945)
- also known (ak) up to 2000
- ak to 2012

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!*

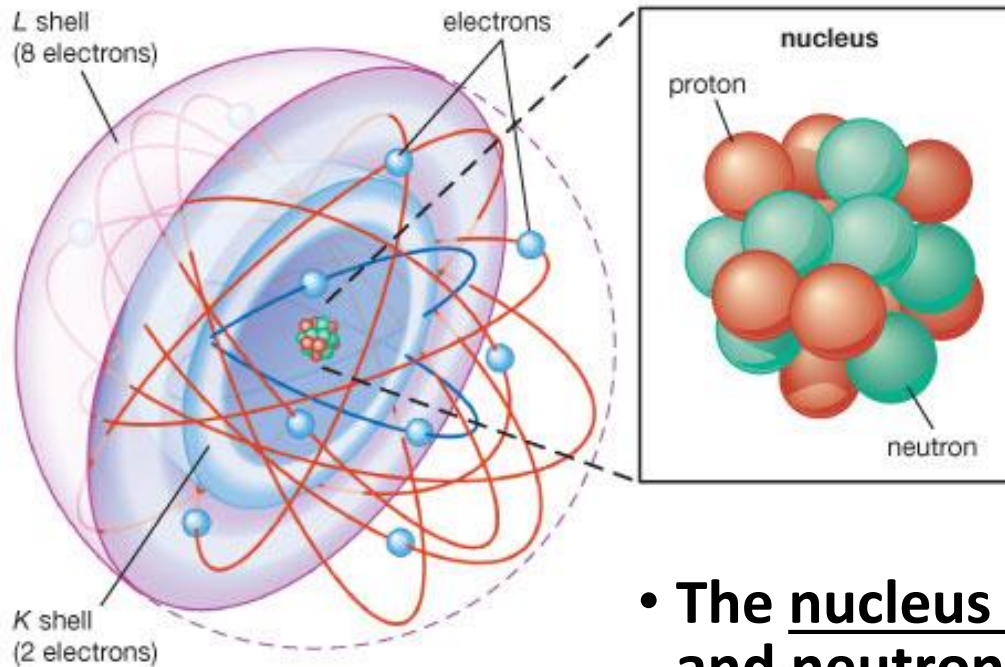


Periodic Table Showing Isotopes

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

What Holds an Atom Together?

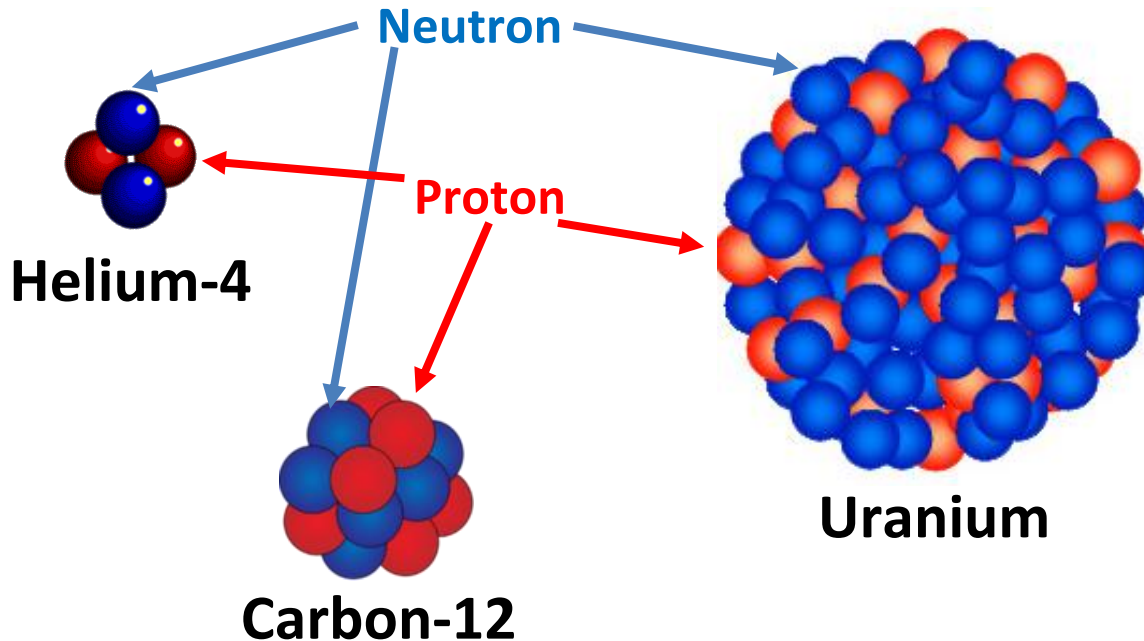


- The electrons are kept in orbit around the nucleus due to an electromagnetic field of attraction between the positive (+) charge of the protons and the negative (-) charge of the electrons.

- 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!)*.

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...

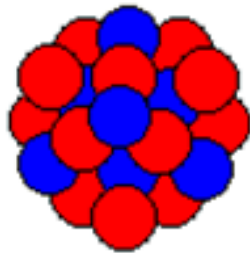
- A stable atom is an atom that has enough binding energy to hold the nucleus together permanently.

...radioactivity!

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**: ${}^4\text{He}$ (alpha particles), β particles (electrons), γ rays (energetic photons), neutrons.

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



spontaneous decay

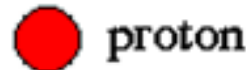


alpha particles (He nuclei)



gamma ray

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



proton



beta particle (electron)



neutron

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*.

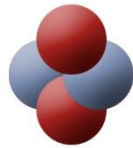
<u>Radioisotope</u>	<u>Half-life</u>
Polonium-215	0.0018 seconds
Bismuth-212	60.5 seconds
Sodium-24	15 hours
Iodine-131	8.07 days
Cobalt-60	5.26 years
Radium-226	1600 years
Uranium-238	4.5 billion years

Ionizing Radiation

Ionizing radiation 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”)