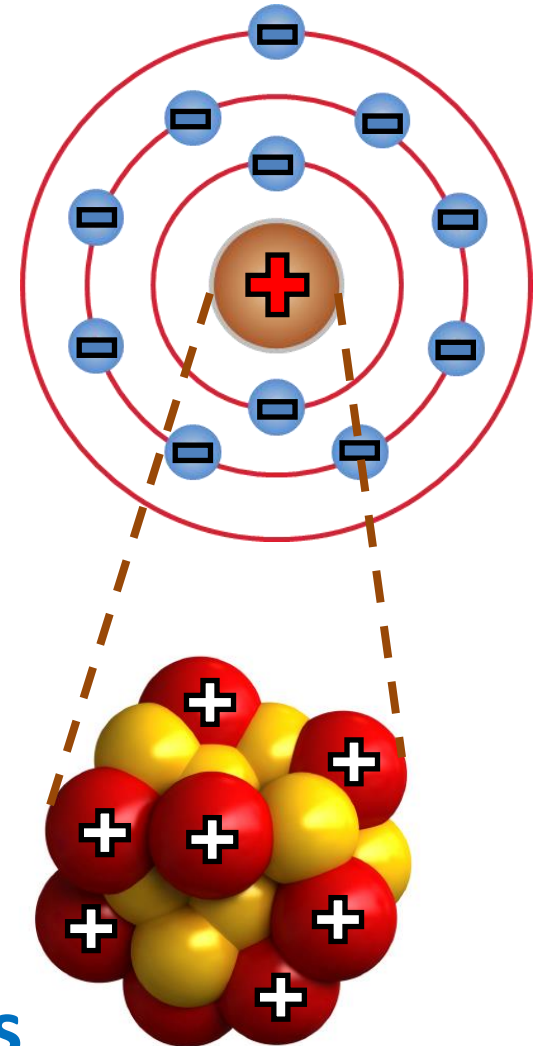


Atomic Structure Summary

- 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



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



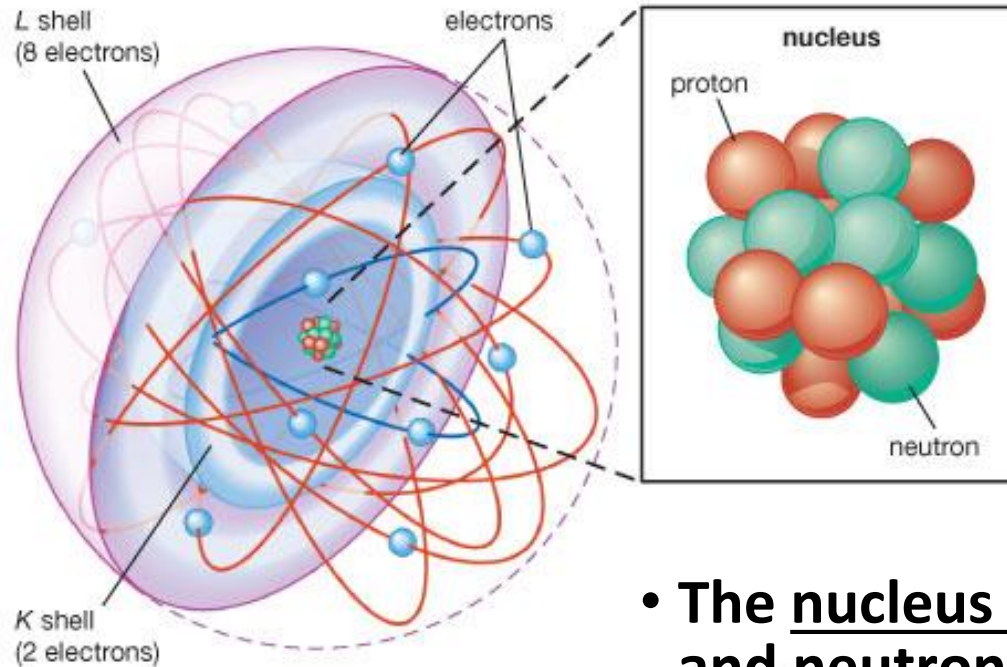
Most elements have more than one isotope.



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



What Holds an Atom Together?

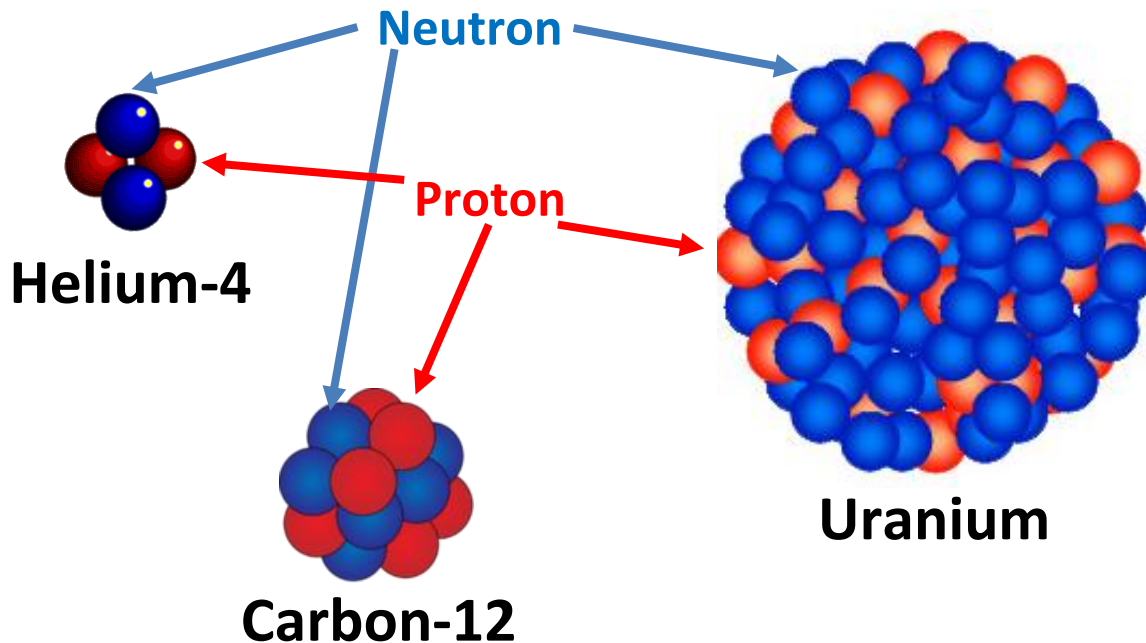


- The electrons are kept in orbit around the nucleus due to an electromagnetic field of attraction between the positive (+) charge of the protons and the negative (-) charge of the electrons.

- 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!

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;"> <p>Element Symbol — Li</p> <p>Element Name — Lithium</p> </div> <div> <p>6, 7 — Mass Numbers of Stable Isotopes</p> <p>3 — Atomic Number</p> </div> </div>																	
23 Na 11 Sodium	24, 25, 26 Mg 12 Magnesium																		
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 94-103 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, 126, 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 83 Bi 83 Bismuth	none 84 Po 84 Polonium	none 85 At 85 Astatine	none 86 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 61 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	none	none Ac 89 Actinium	none Th 90 Thorium	none Pa 91 Protactinium	none U 92 Uranium	none 93 Np 93 Neptunium	none Pu 94 Plutonium	none 95 Am 95 Americium	none 96 Cm 96 Curium	none 97 Bk 97 Berkelium	none 98 Cf 98 Californium	none 99 Es 99 Einsteinium	none 100 Fm 100 Fermium	none 101 Md 101 Mendelevium	none 102 No 102 Nobelium	none 103 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**.
- Naturally occurring in the Earth's crust, **Potassium-40 and various isotopes of Uranium, Thorium, Radium, and Radon** are the most commonly found radioactive elements.



Discovery of Radioactivity

- Henri Becquerel, 1896:

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

- Marie Sklodowska-Curie and Pierre Curie, 1898:

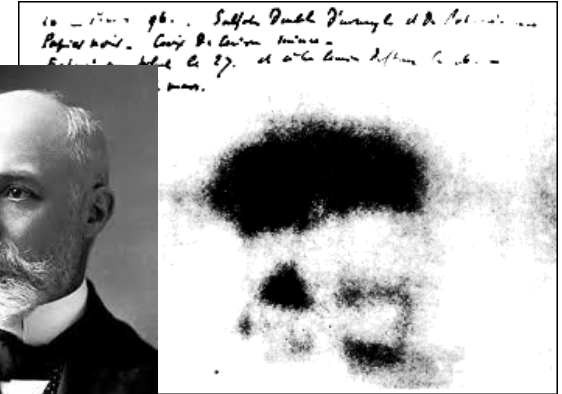
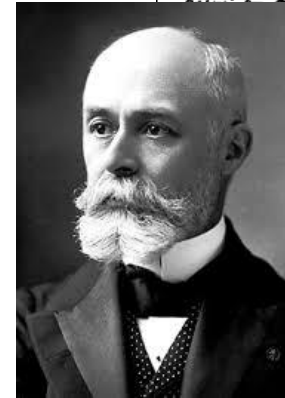
- conducted a **systematic study** to determine which other elements and compounds emitted “mysterious radiation” that they called “radioactivity”;

- isolated a new radioactive element, polonium (named in honor of Marie's home country);

- four years later, discovered an even more intensely radioactive substance, which they called radium.

- Ernest Rutherford and Frederick Soddy, 1899-1903:

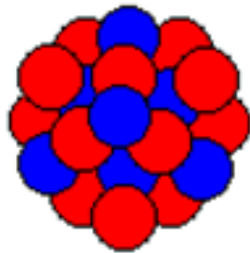
- discovered **three different types of radiation** “rays” with very different powers of penetration, introduced the term “half-life”, and **proposed that atoms were not conserved in radioactive emissions.**



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

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")**

Sources of Background Radiation

Radioactive material is fairly common in nature and our daily life, and generally pretty harmless in that state.

