Unit 1: Atomic Structure & Properties

1.1 Moles & Molar Mass

- 6.02 x 10^{23} things (Avogadro's Number) (N_A)
- Gram formula mass
- Basic dimensional analysis
  - Grams to moles, moles to grams, grams to molecules, grams to atoms

Example Stoichiometry

Grams to Moles

- How many moles of NaCl are contained in 48 g of NaCl?

Moles to Grams

- How many grams of C_2H_6 are contained in 18.7 moles of C_2H_6?

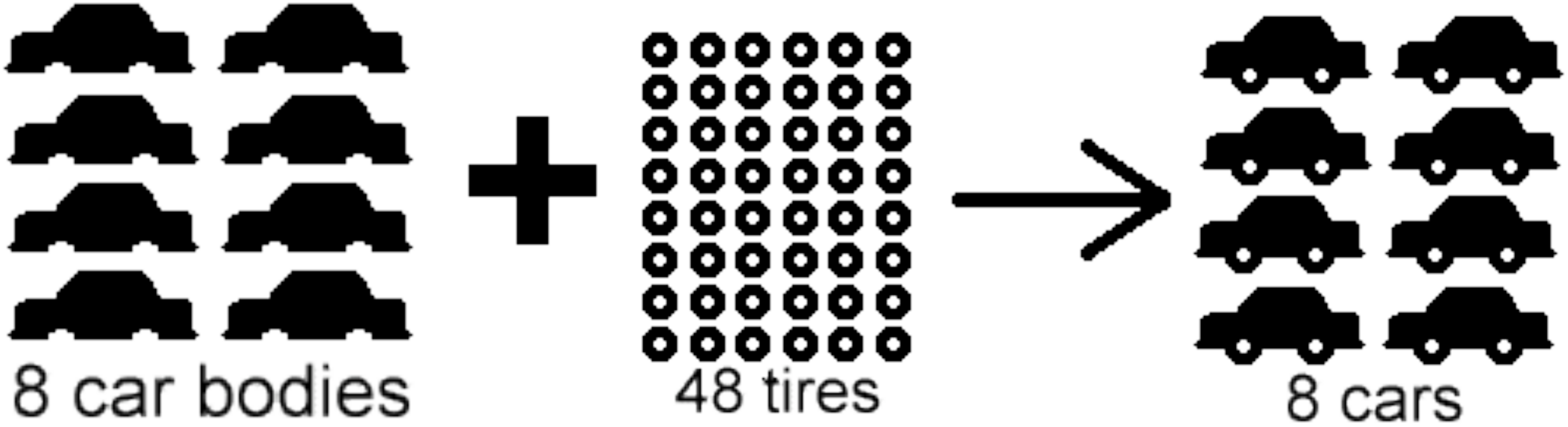
Grams to Molecules

- How many water molecules are contained in 56 g of a pure sample of H_2O?

Grams to Atoms

- How many hydrogen atoms are contained in 56 g of a pure sample of H_2O?

Limiting Reagent



plus 16 tires
excess

Sample Limiting Reagent Question

A 2.00 g sample of ammonia is mixed with 4.00 g of oxygen. Which is the limiting reactant and how much excess reactant remains after the reaction has stopped?

1. Create a balanced equation for the reaction:

   $\_\_\ NH_{3(g)} + \_\_\ O_{2(g)} \rightarrow \_\_NO_{(g)} + \_\_H_2O_{(g)}$

2. Use stoichiometry to calculate how much one product would be produced by **each** reactant. *(NOTE: It does not matter which product you choose for your calculations, but the same product must be used for both reactants so that the amounts can be compared.)*
3. Math to follow …

Sample Limiting Reagent Question

If 15 grams of copper (II) chloride react with 20 grams of sodium nitrate, how much sodium chloride can be formed?

$$\_\_\_\ CuCl_2 + \_\_\_\ NaNO_3 \rightarrow \_\_\_\ Cu(NO_3)_2 + \_\_\_\ NaCl$$

What is the limiting reagent for the reaction?

How much of the non-limiting reagent is left over (excess) in this reaction?

Percent Yield

Error in experiments result in less product obtained than we originally calculated. The amount we get is the Percent Yield.

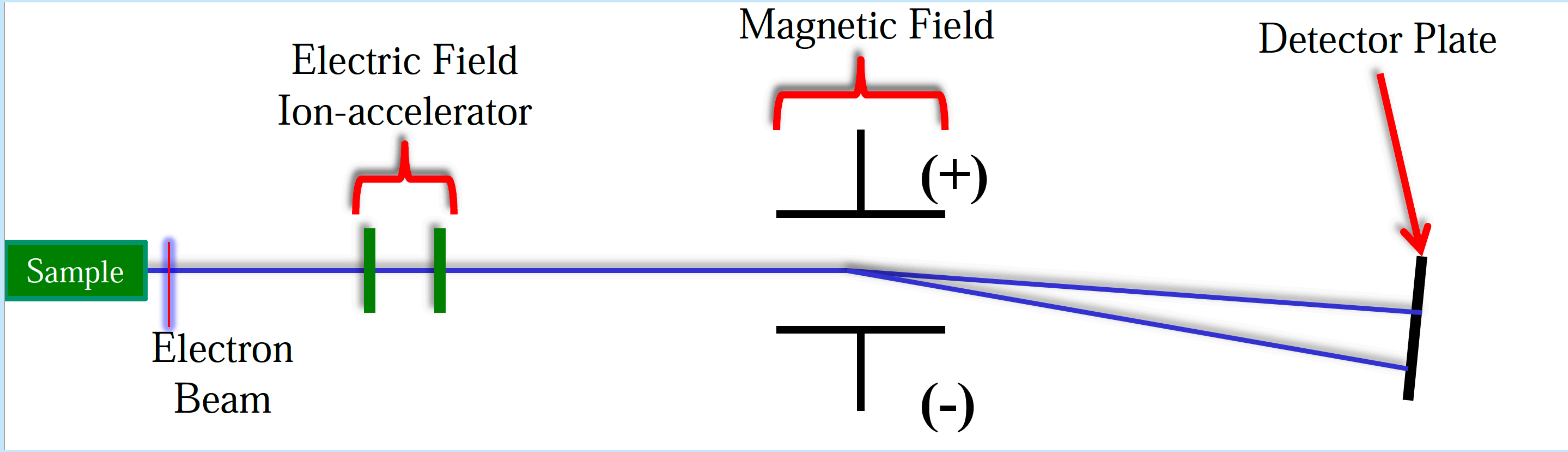
Percent = (Part / Whole) x 100

% Yield = amount you got / amount you should have gotten x 100

Using the maximum yield from the previous problem, if 11.3 grams of sodium chloride are formed in the reaction, what is the percent yield of this reaction?

1.2 Isotopes & Mass Spectroscopy

- Used to compare masses of isotopes
- Atoms ionized & accelerated through a magnetic field
- Lighter isotopes deflected more
- Can determine average atomic mass (weighted atomic mass) from the resultant spectrum



Atomic & Mass Numbers

- Mass Number (A)
  - Equal to the number of protons plus the number of neutrons

$$^{14}_{6}\mathrm{C}$$

Number of neutrons present in this isotope?

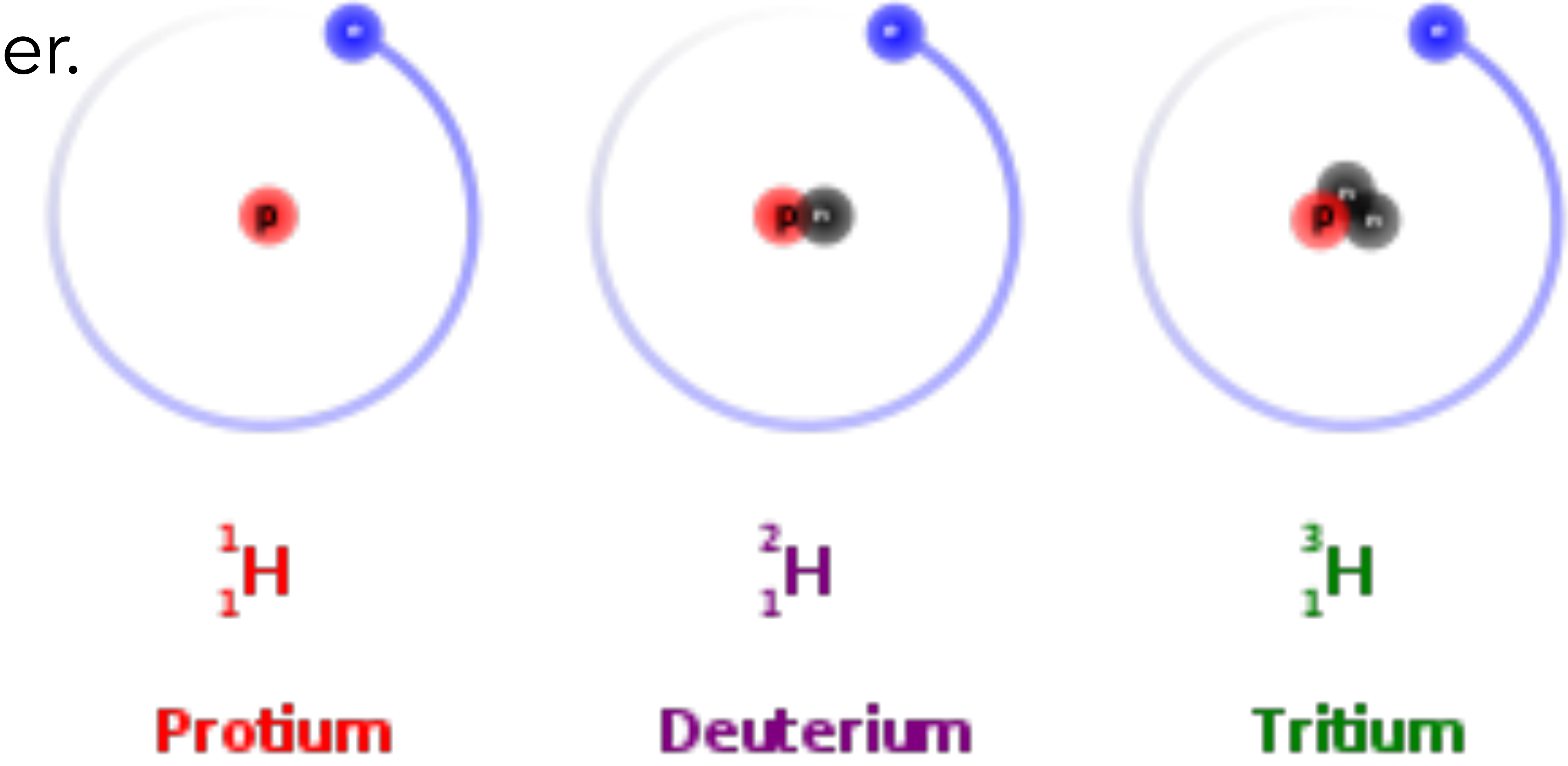
- Atomic Number (Z)
  - Equal to the number of protons (or electrons) in a *neutral* atom

Isotopes

- Isotopes of an element have the same number of protons, but different numbers of neutrons.

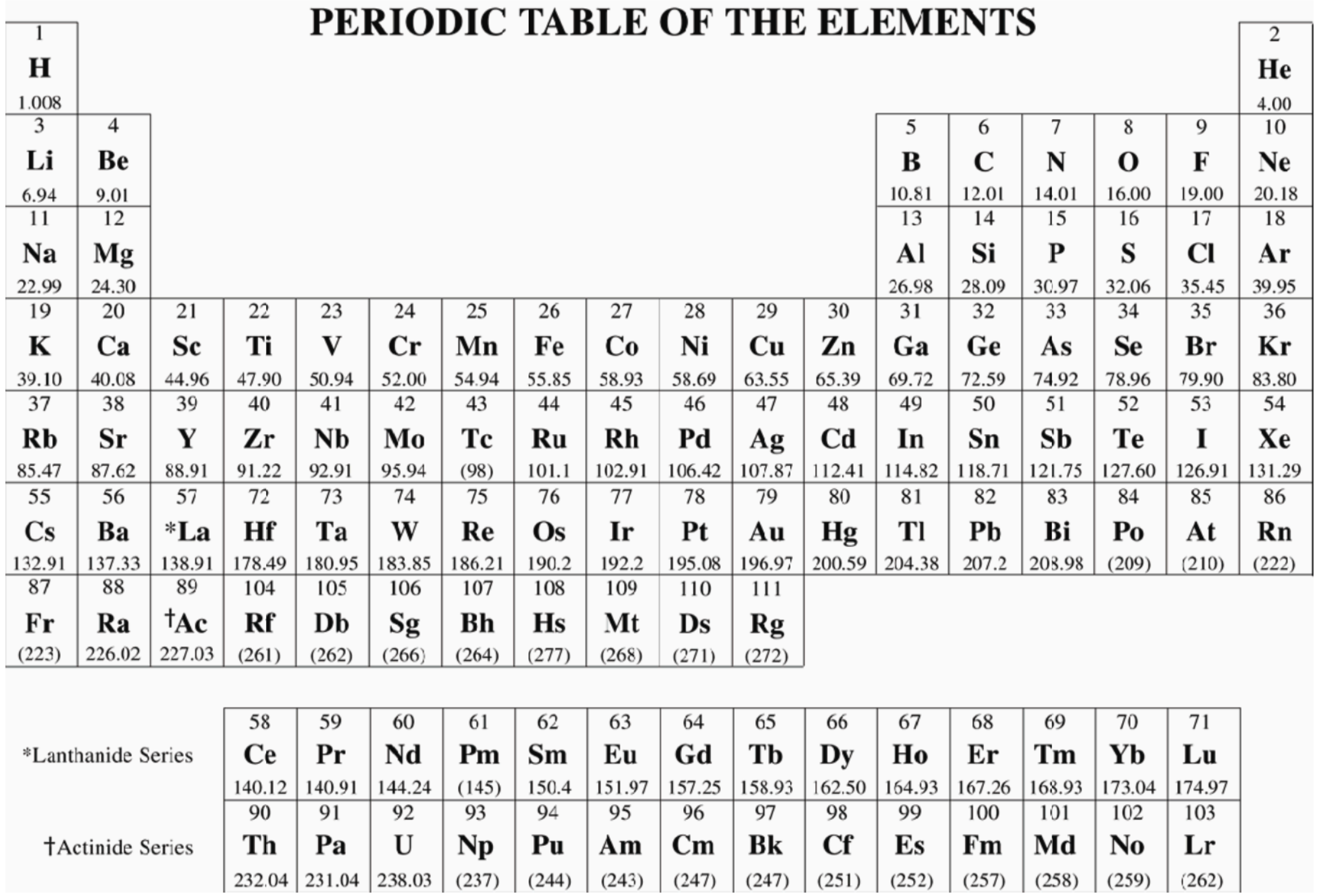
- Isotopes have identical chemical behavior

- C-14 and C-12 will both react with Oxygen in exactly the same way (as will H-1 and H-2 with Oxygen to form water.



Average Atomic Mass

- Atomic Mass given on the PToE is a weighted average of all naturally occurring isotopes of the element.
  - The ratio of the isotopes is always the same.
  - Mass Spectroscopy can be used to calculate average mass.



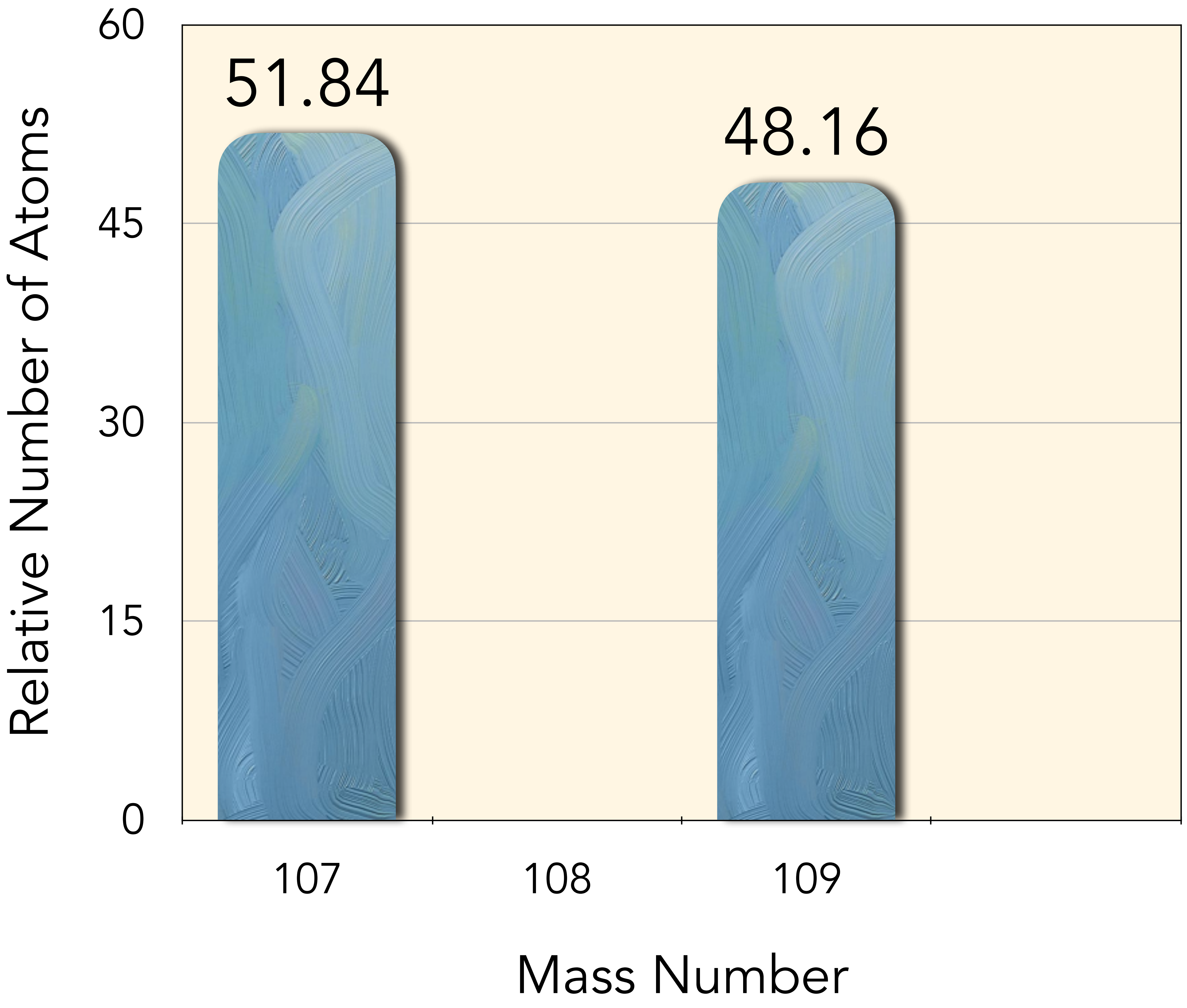
PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.008																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

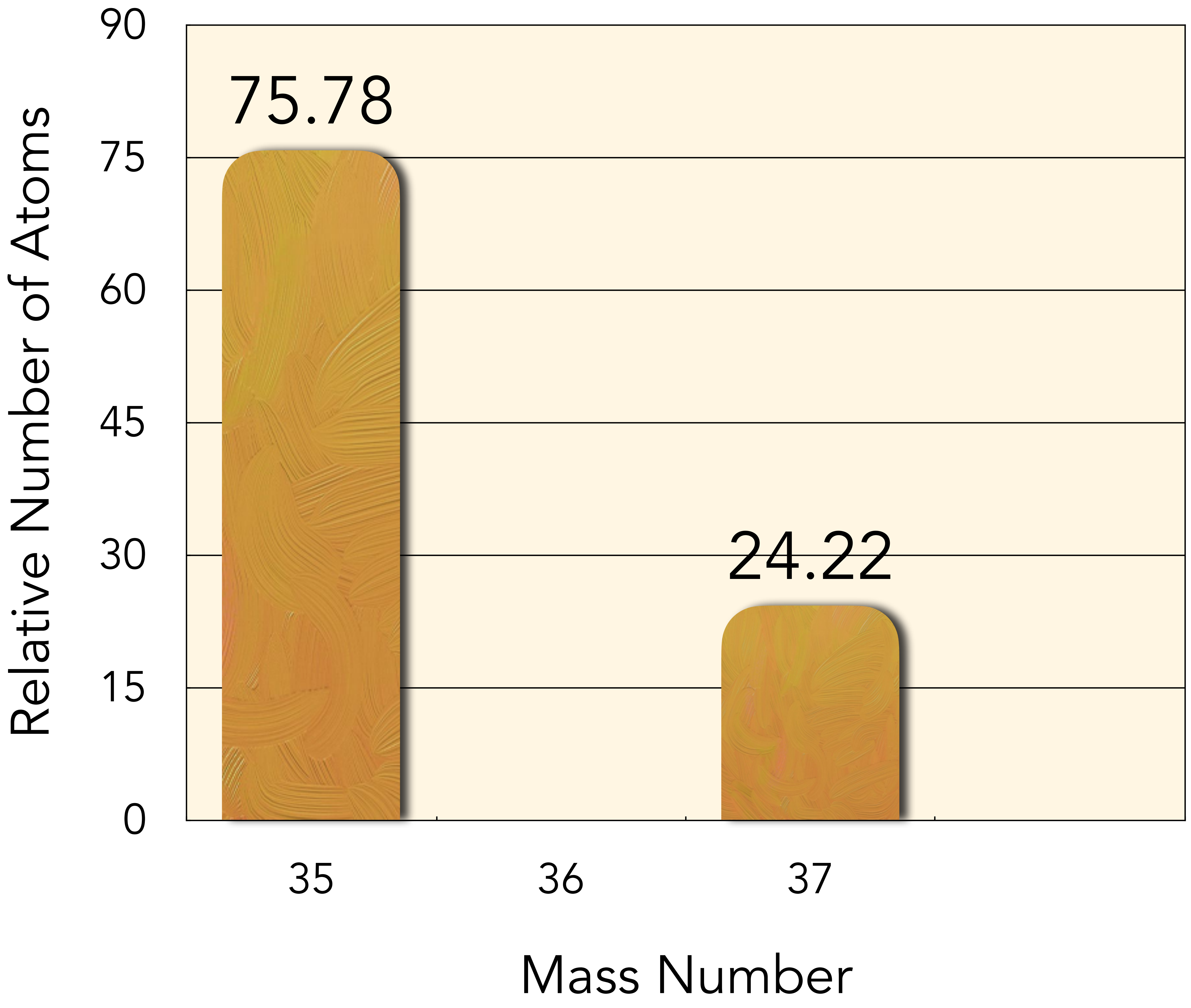
Average Atomic Mass Example

A pure sample of silver was vaporized and injected into a mass spectrometer. The data was plotted. The mass value for Ag-109 is 108.90476 amu. Find the mass of Ag-107.



Another Example

Use the mass spectrum data to find the average atomic mass of the element in question and identify the element. The exact mass values of the isotopes are 34.969 amu and 36.966 amu.



1.3 Elemental Composition of Pure Substances
1.4 Composition of Mixtures

Pure Samples

Law of Definite Proportions

Mass Percent

Empirical & Molecular Formulas

Pure Samples & Mixtures

Pure Sample

- Contains particles from one type of atom, molecule or formula unit (e.g. an ionic solid such as NaCl)

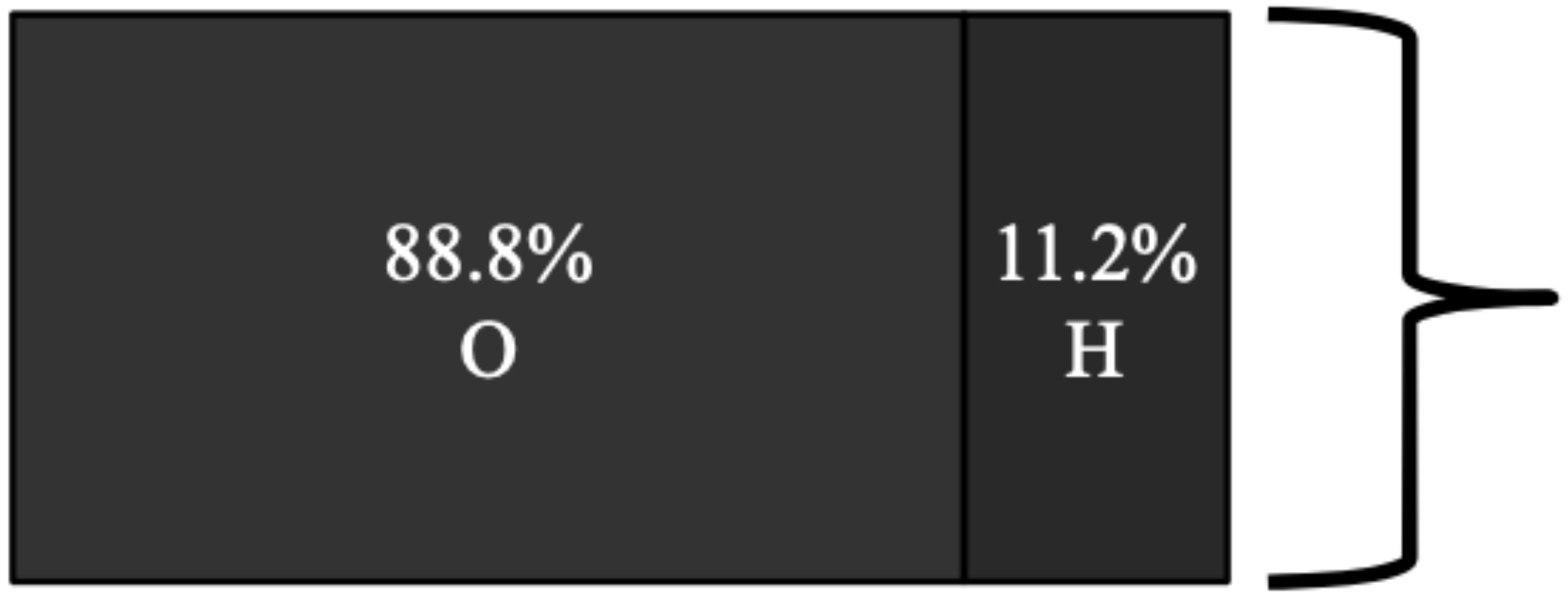
Mixture

- Contains particles from more than one type of atoms, formula unit or molecule

The History of the Atom

Joseph Proust (1754-18-26)

- ***The Law of Definite Proportions***
- *Different pure samples of the same compound always contain the same proportions of each element by mass.*
  - Water is always 88.8% oxygen and 11.2% hydrogen by mass.



Water is always found in these proportions by mass.


River Water

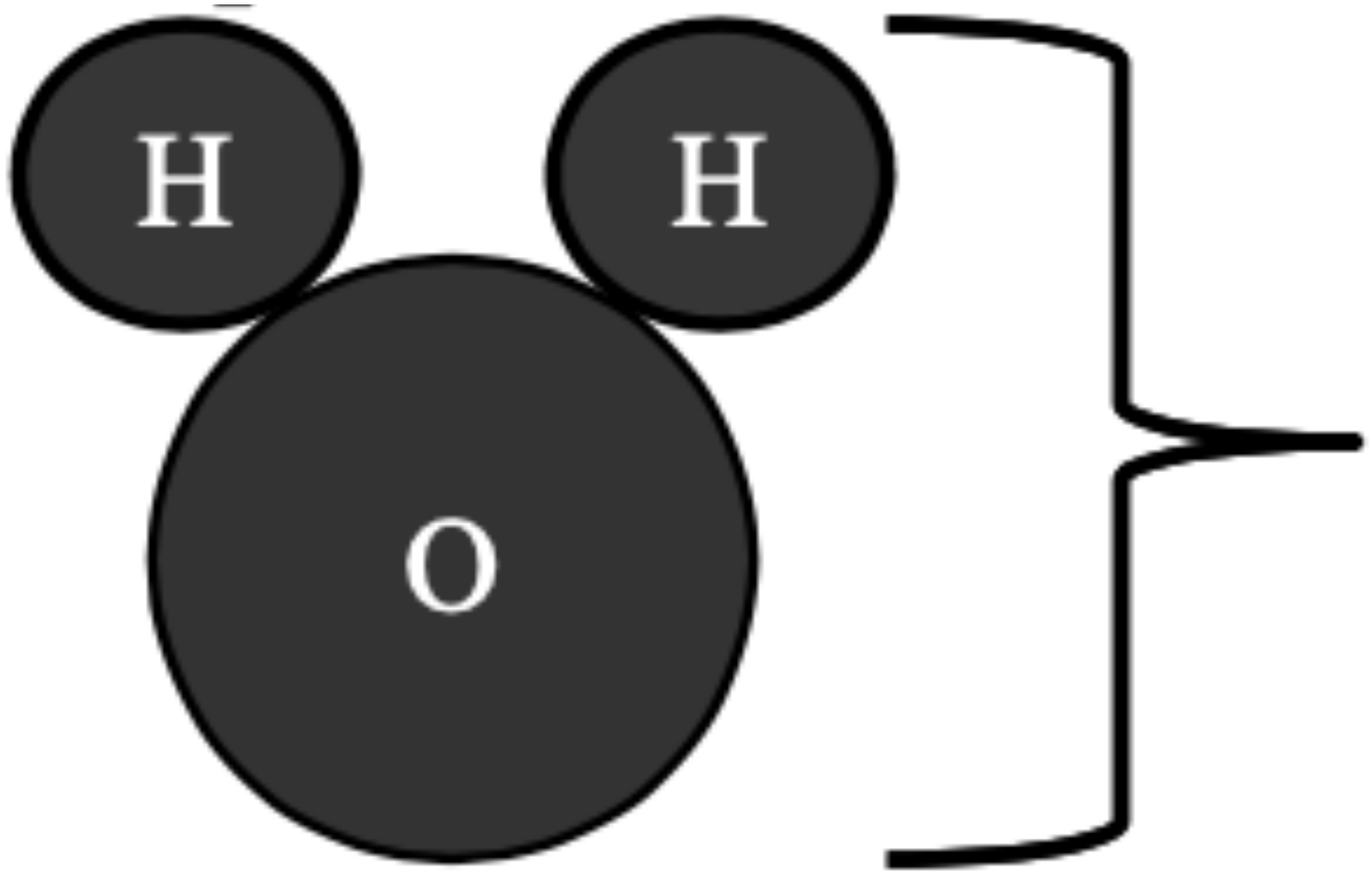

Rainwater


Tap Water

The History of the Atom

John Dalton (*Billiard Ball Model*)

- tiny invisible particles - a particular compound would always be composed of equal numbers of each type of element.
- same thing as Proust…



Water is always composed of the same number of hydrogen atoms and the same number of oxygen atoms.

Mass Percent

- The percentage by mass of an element in a pure sample of a compound or a component in a substance.

- Last year we showed this as Mass% = Part/Whole x 100
  - Same thing this year!

What is the mass % of Iron in a pure sample of $FeTiO_3$?

A tablet contains 0.025 mg of vitamin D. The entire table has a mass of 0.115 g. Calculate the mass percent of vitamin D in the tablet.

Empirical & Molecular Formulas

- Empirical Formula - lowest whole number ratio of elements in a compound.

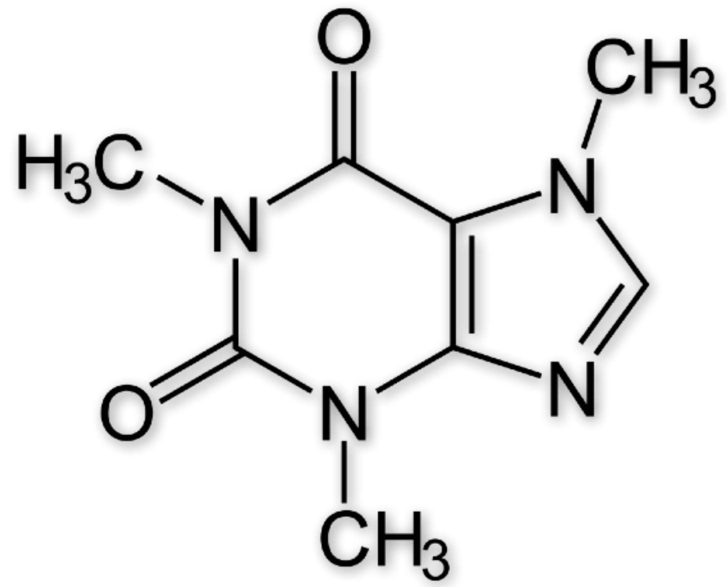
- Empirical formulas can be determined via 2 methods:
  1. %composition by element
  2. Combustion Analysis (*POGIL*)

- Molecular Formula - based on the Empirical Formula and the gram formula mass of the compound. Actual number of each type of atom in molecule.

Example: Empirical Formula

A sample of caffeine was found to contain 49.5% carbon, 28.9% nitrogen, 16.5% oxygen and 5.1% hydrogen by mass. Find the empirical formula for caffeine.

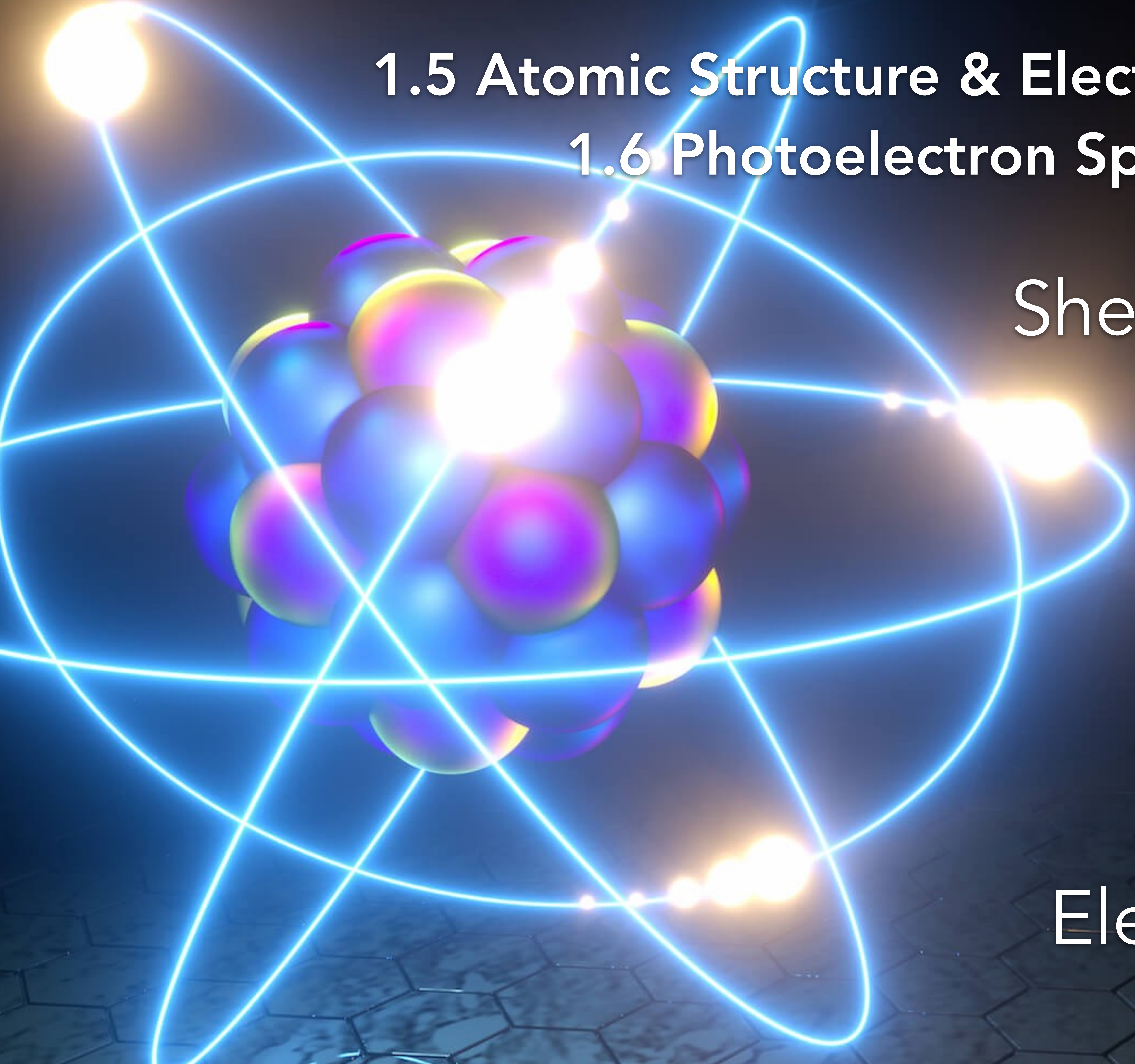
Molecular Formula



The molar mass (gram formula mass) of caffeine is 194.2 g/mol. Find the molecular formula for caffeine.

Empirical Formula$_{\text{caffeine}}$ = $C_4H_5N_2O$

1.5 Atomic Structure & Electron Configuration
1.6 Photoelectron Spectroscopy



Shell Model of an Atom

Coulomb's Law

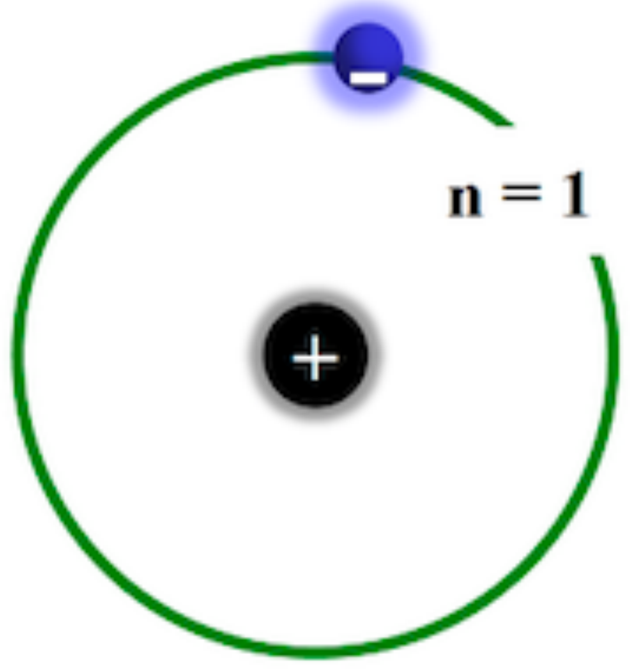
Shielding Effect

1st Ionization Energy

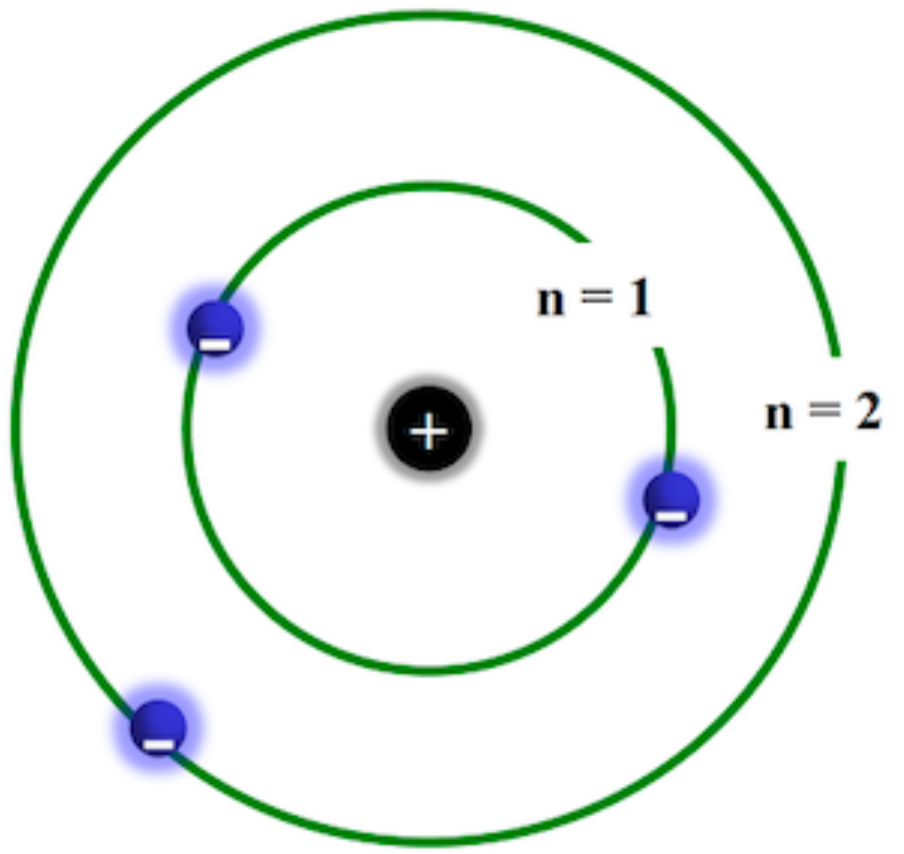
Electron Configuration

The Shell Model of the Atom

- Electrons move around the positively charged nucleus in circular orbits.
- Only certain orbits (shells) are allowed, and each orbit is a fixed distance from the nucleus.
- An electron within a shell has a set, quantized energy level.
- Forces of attraction between the electrons and the nucleus result from opposite charges.



Hydrogen



Coulomb's Law

$$F = k\frac{q_1 q_2}{d^2}$$

f = Force of attraction

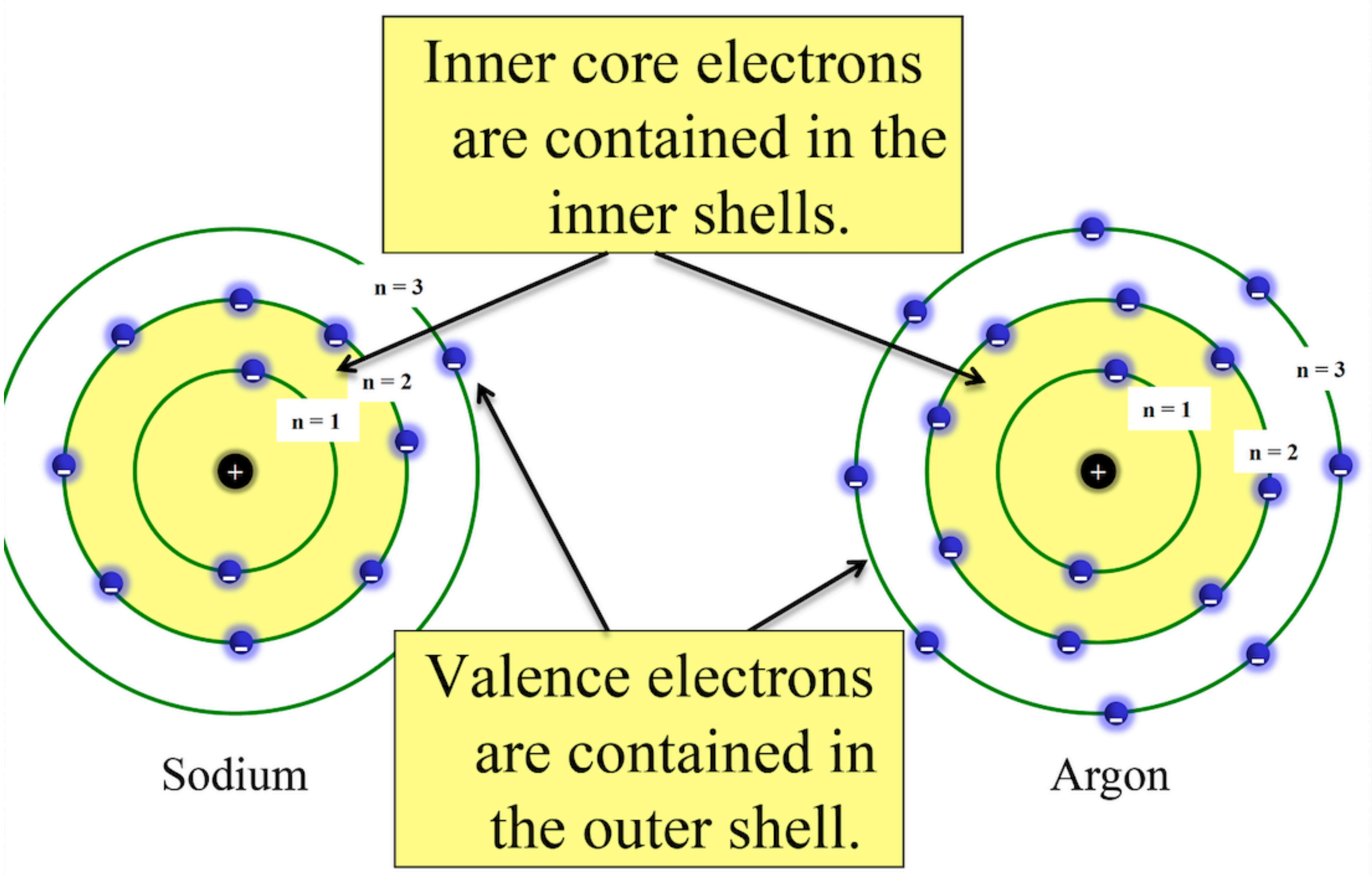
k = Constant

q = Magnitude of charge associated with a particle - protons or electrons

d = Distance between charged particles

The force of attraction decreases as the distance between the outermost electron and the protons increases.

Inner Core & Valence Electrons



Inner core electrons are contained in the inner shells.

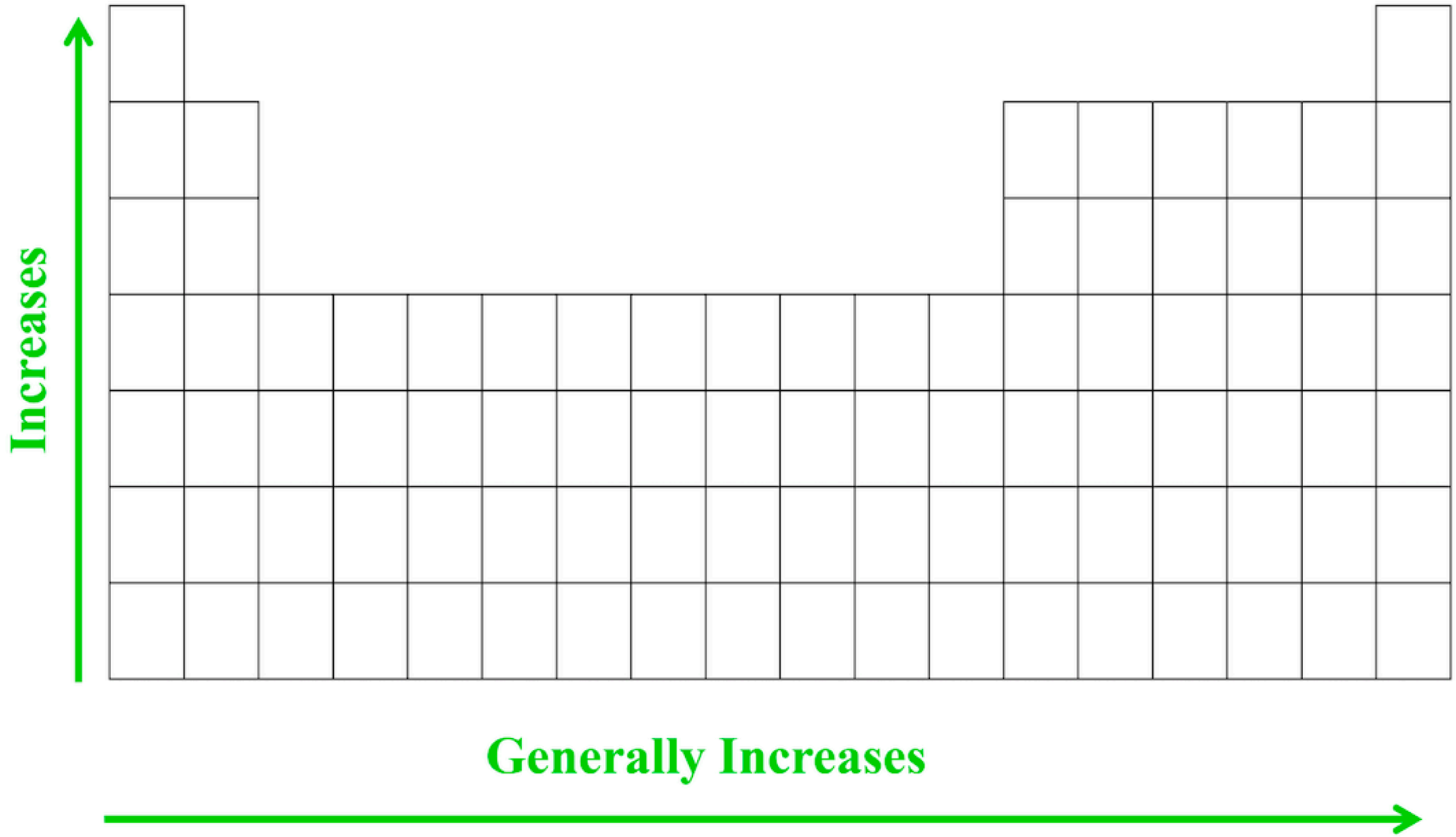
Valence electrons are contained in the outer shell.

Shielding Effect / First Ionization Energy

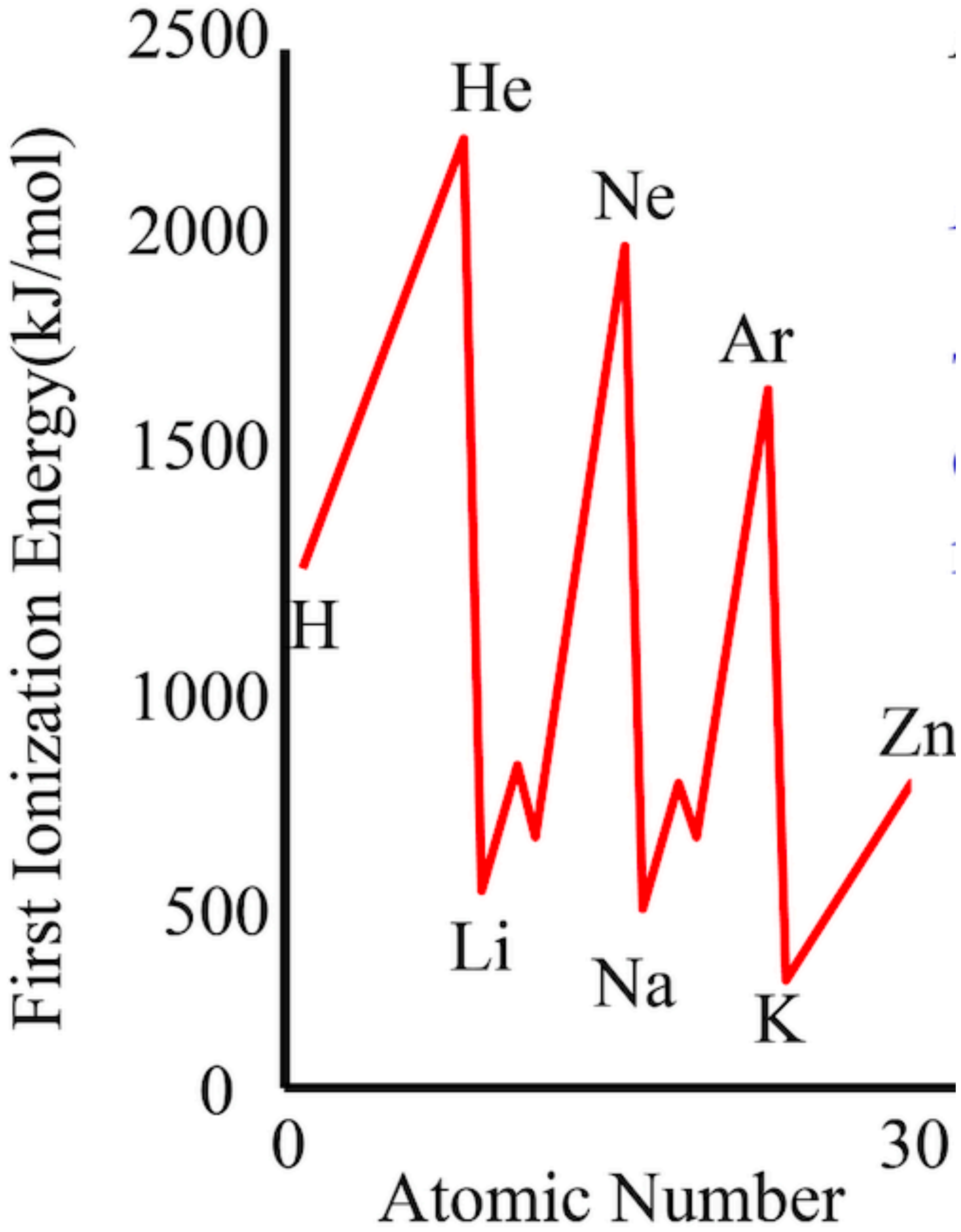
- The electrons that are furthest from the nucleus are partly ‘shielded’ by the inner core electrons.
- This shielding effect (electrostatic repulsion from the inner core electrons) reduces electrostatic attractions between the outer electrons and the nucleus.
- IE - the minimum amount of energy that is required to remove and outermost, least tightly held electron from an atom *in the gas phase*.

$$A(g) \rightarrow A^+(g) + e^-$$

First Ionization Energy (Trends)



First Ionization Energy of H & He



IE_H = 1312 kJ/mol

EI_{He} = 2372 kJ/mol

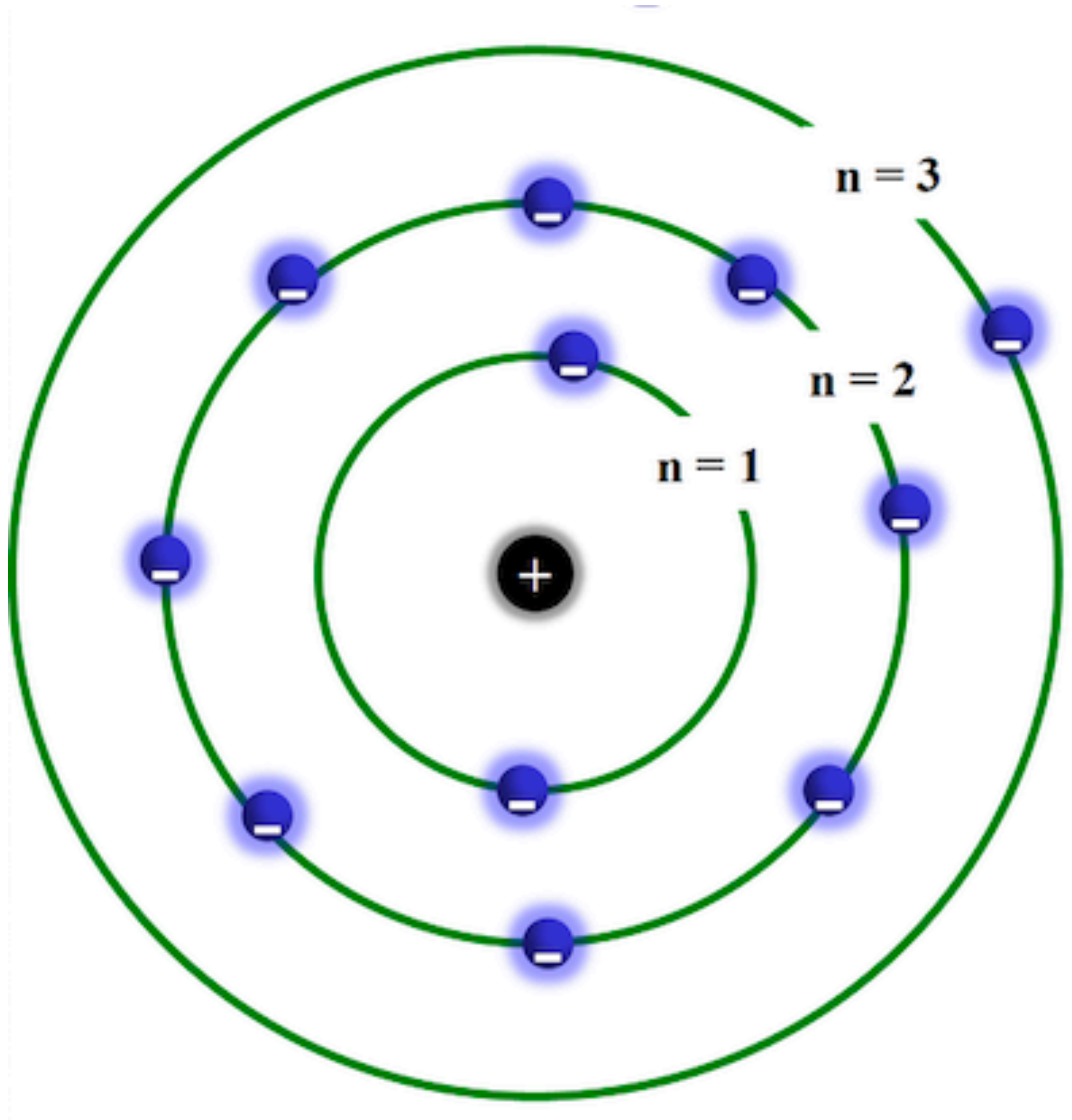
IE_{Li} = 520 kJ/mol

Distance from the nucleus increases from H to Li

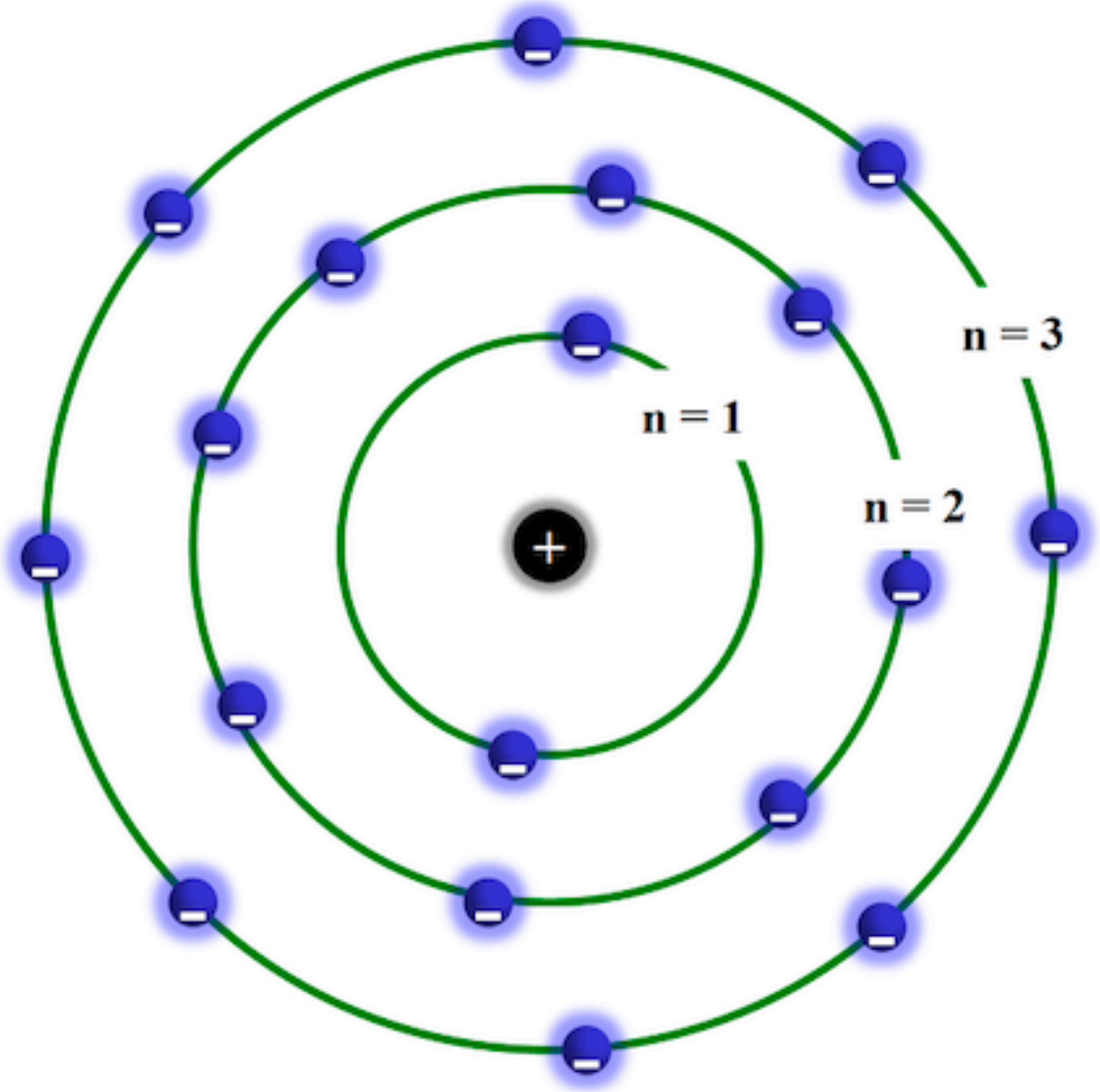
$$F = k\frac{q_1 q_2}{d^2}$$

Evidence of the Shell Model

- Ionization data suggests that electron are arranged in shells.

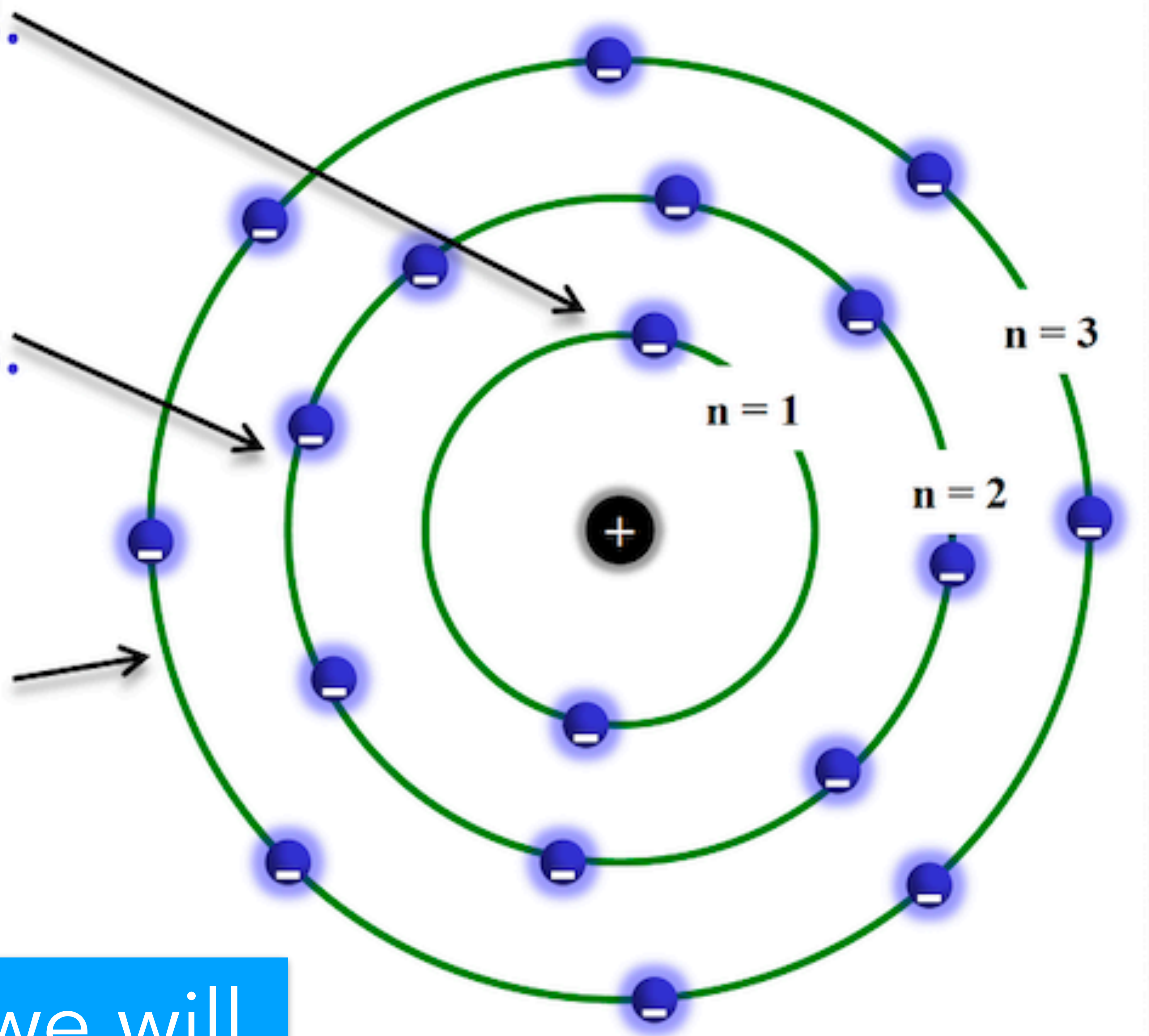


Sodium



Argon

The Shell Model & the Periodic Table



The 1st row of the periodic table has 2 elements and n = 1 can hold 2 electrons.

The 2nd row of the periodic table has 8 elements and n = 2 can hold 8 electrons.

The 3rd row of the periodic table has 8 elements and n = 3 can hold at least 8 electrons.

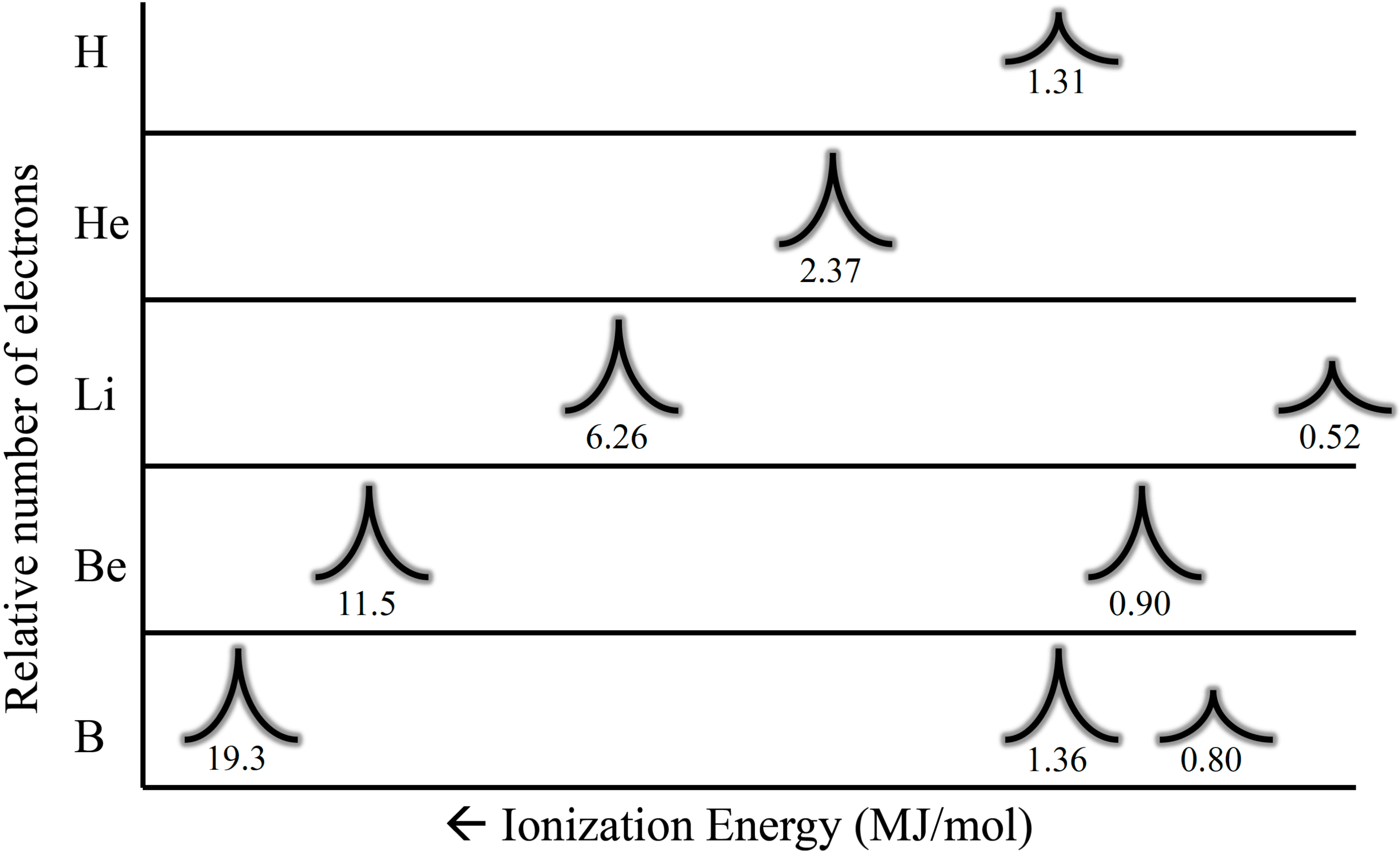
n = 3 can actually hold 18 electrons, as we will see in the next part of this lesson.

1.6 Photoelectron Spectroscopy

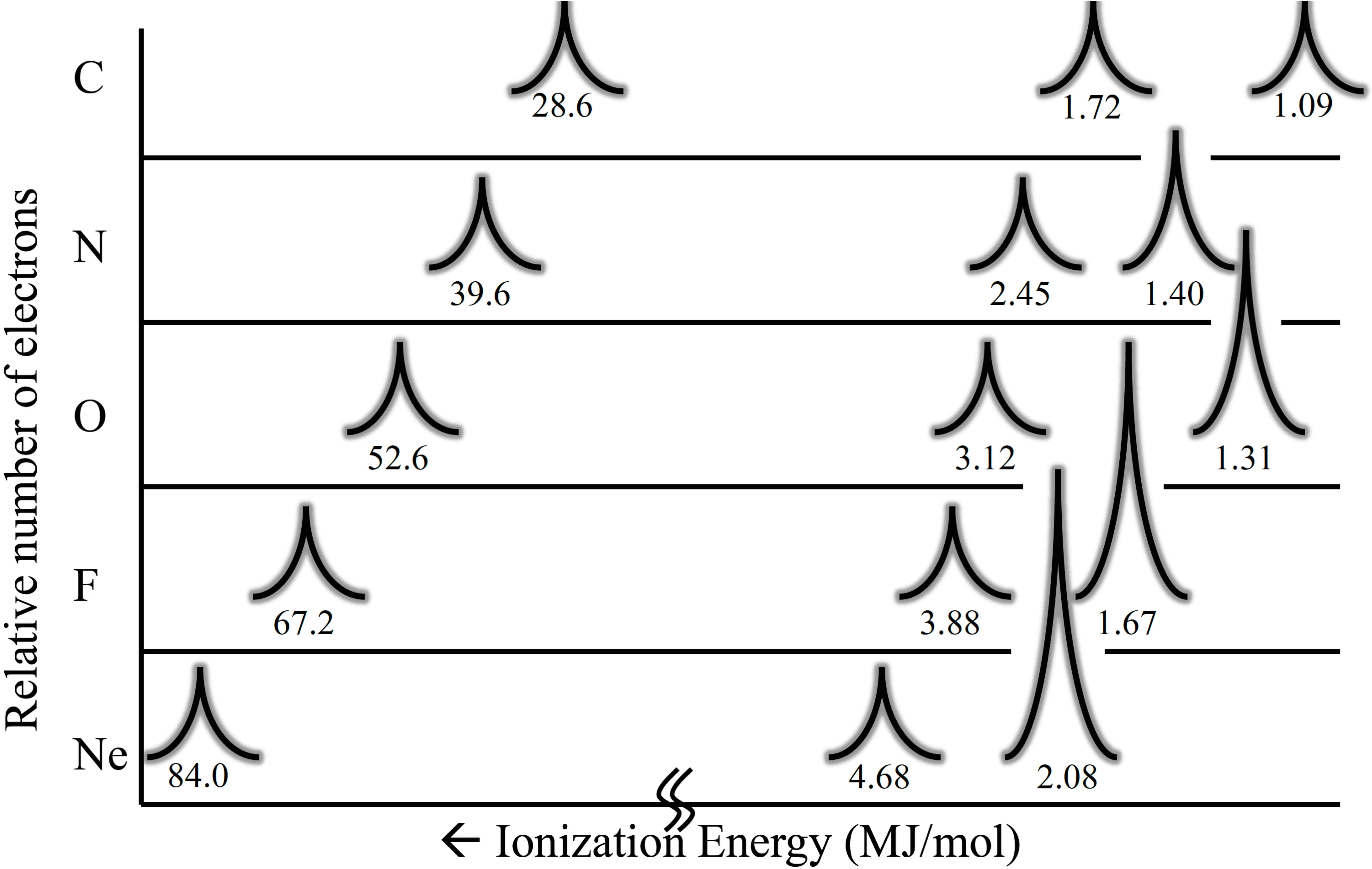
- High energy photons remove electrons from any shell, not just the valence shell.
- KE of ejected electrons is determined
- Frequency of photons is recorded
- Ionization energy for any electron is calculated:

$$IE = h\nu - KE$$

Photoelectron Spectra



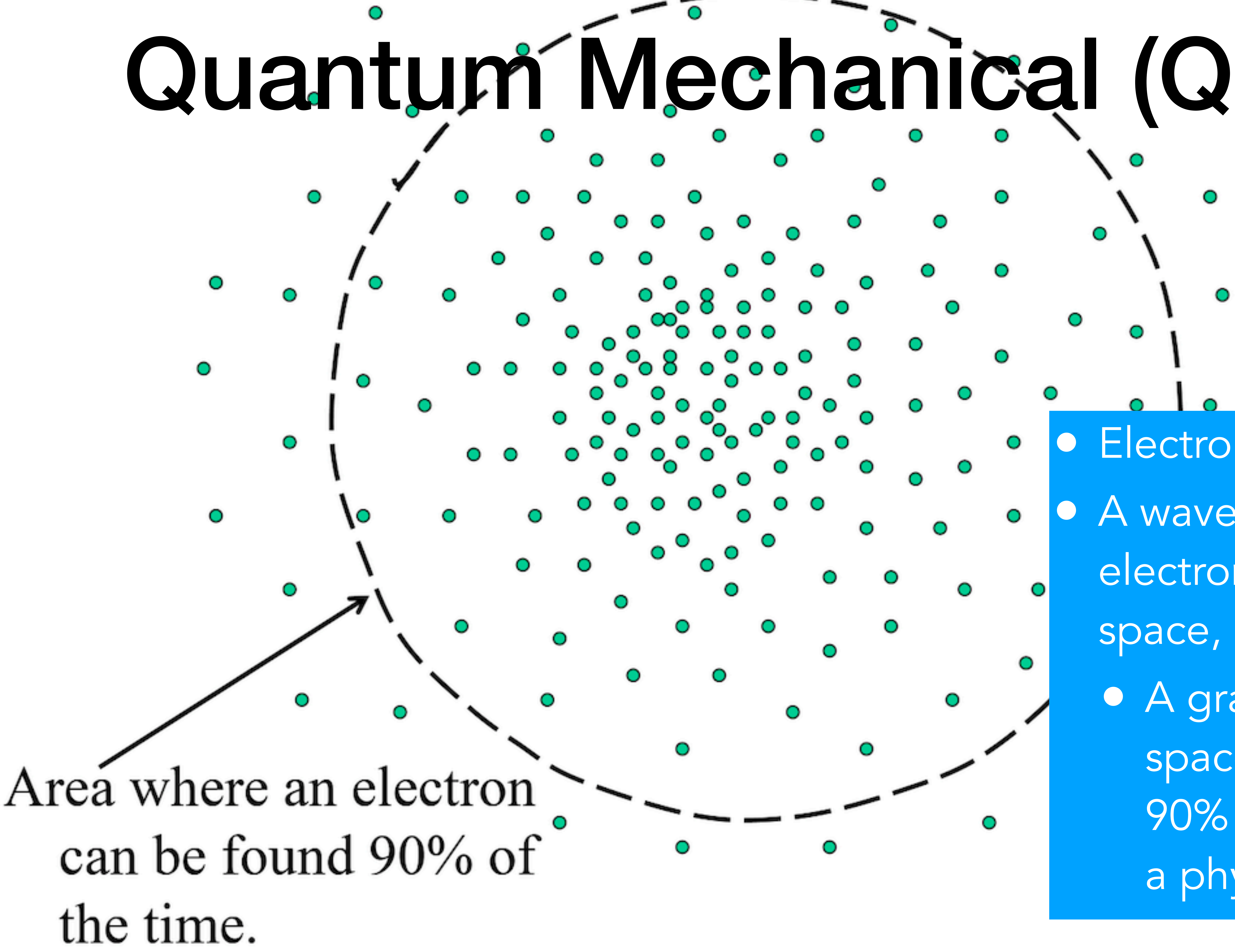
Photoelectron Spectroscopy



The Shell Model & PES

- Does the shell model still work?? Could it be refined??
- Bohr postulated that all electrons are in a given shell at the same energy level.
- PES data suggest otherwise…2 subshells in n=2 and 3 subshells in n=3
- QUANTUM MECHANICAL MODEL (electron cloud, orbital model)

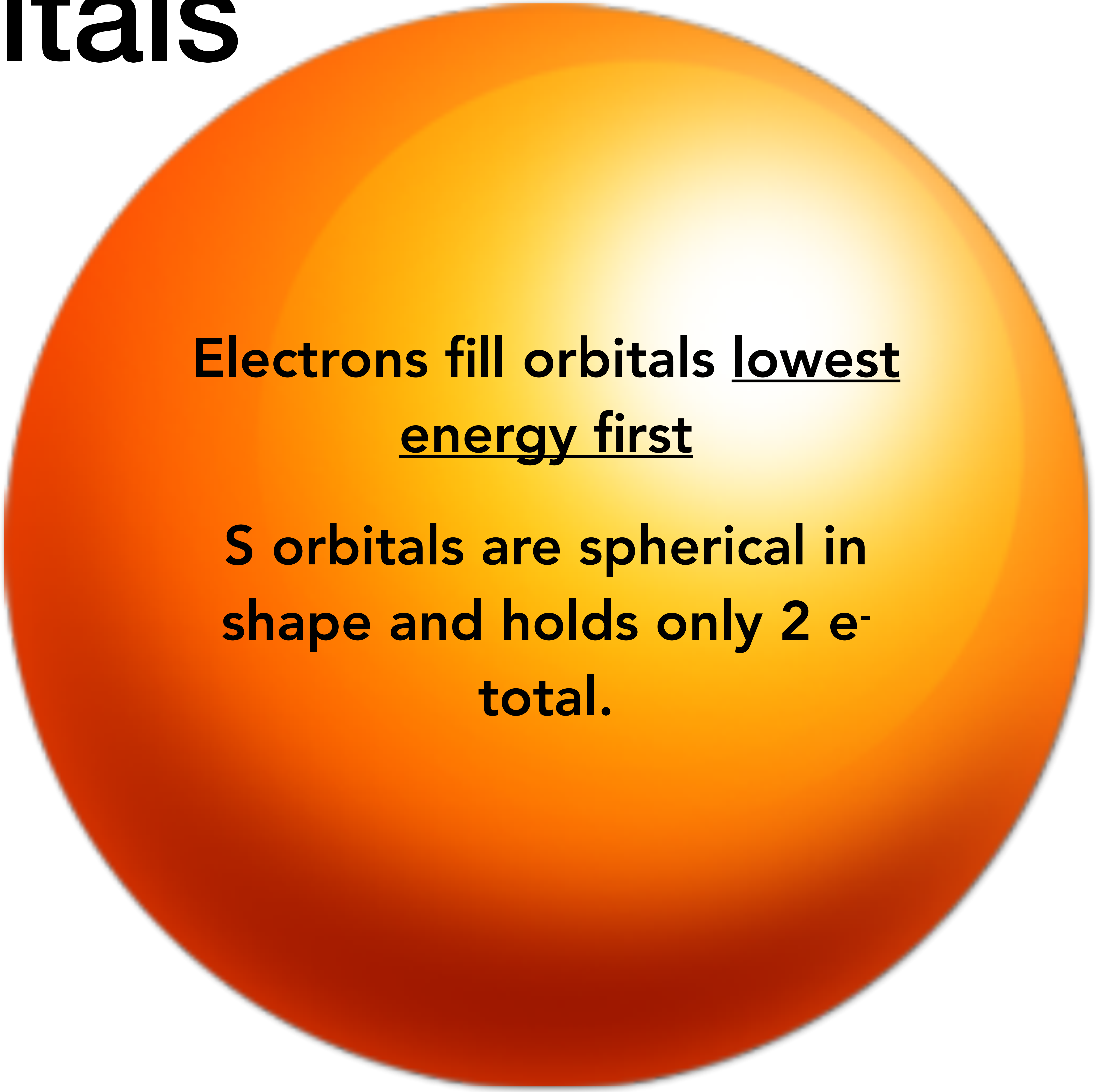
Quantum Mechanical (QM) Model



- Electrons do not follow orbits.
- A wave function describes an electron's possible positions in 3D space, and is often call an **orbital**.
  - A graphical representation of the space an electron will occupy 90% of the time (conceptual, not a physical structure).

s-Orbitals

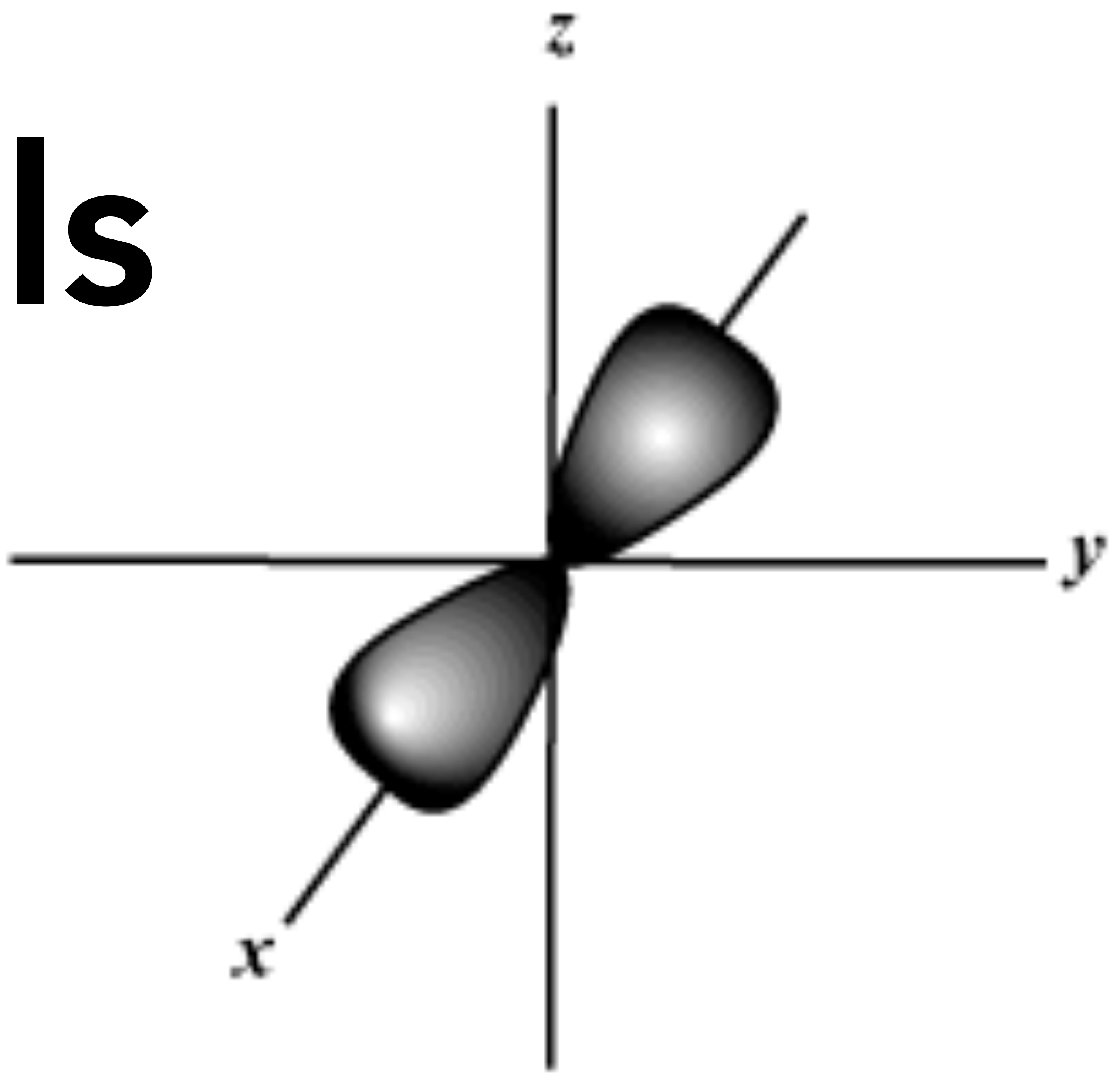
- Each orbital can only hold **2** electrons, each with opposite spins
- **Pauli Exclusion Principle**



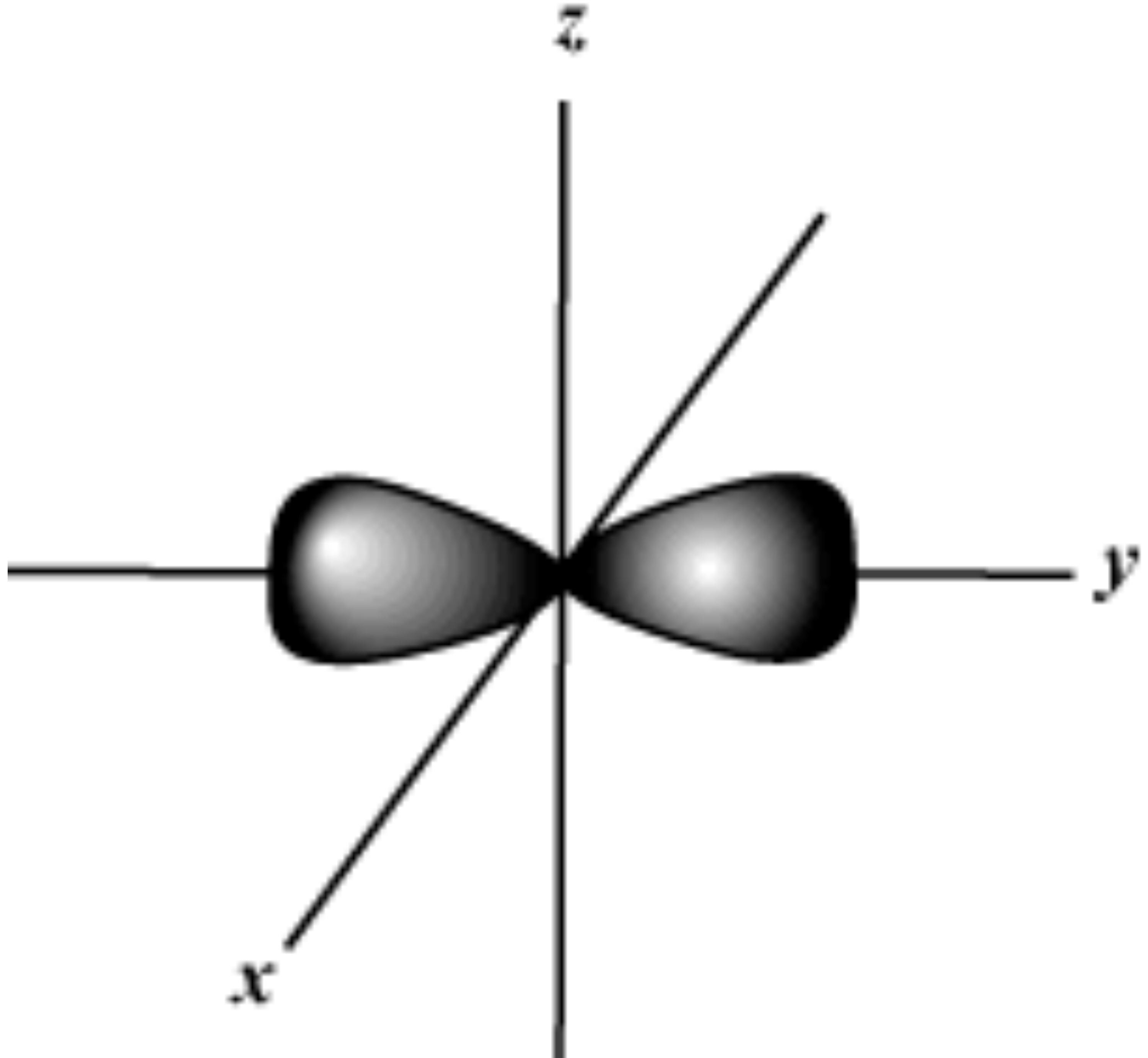
Electrons fill orbitals lowest energy first

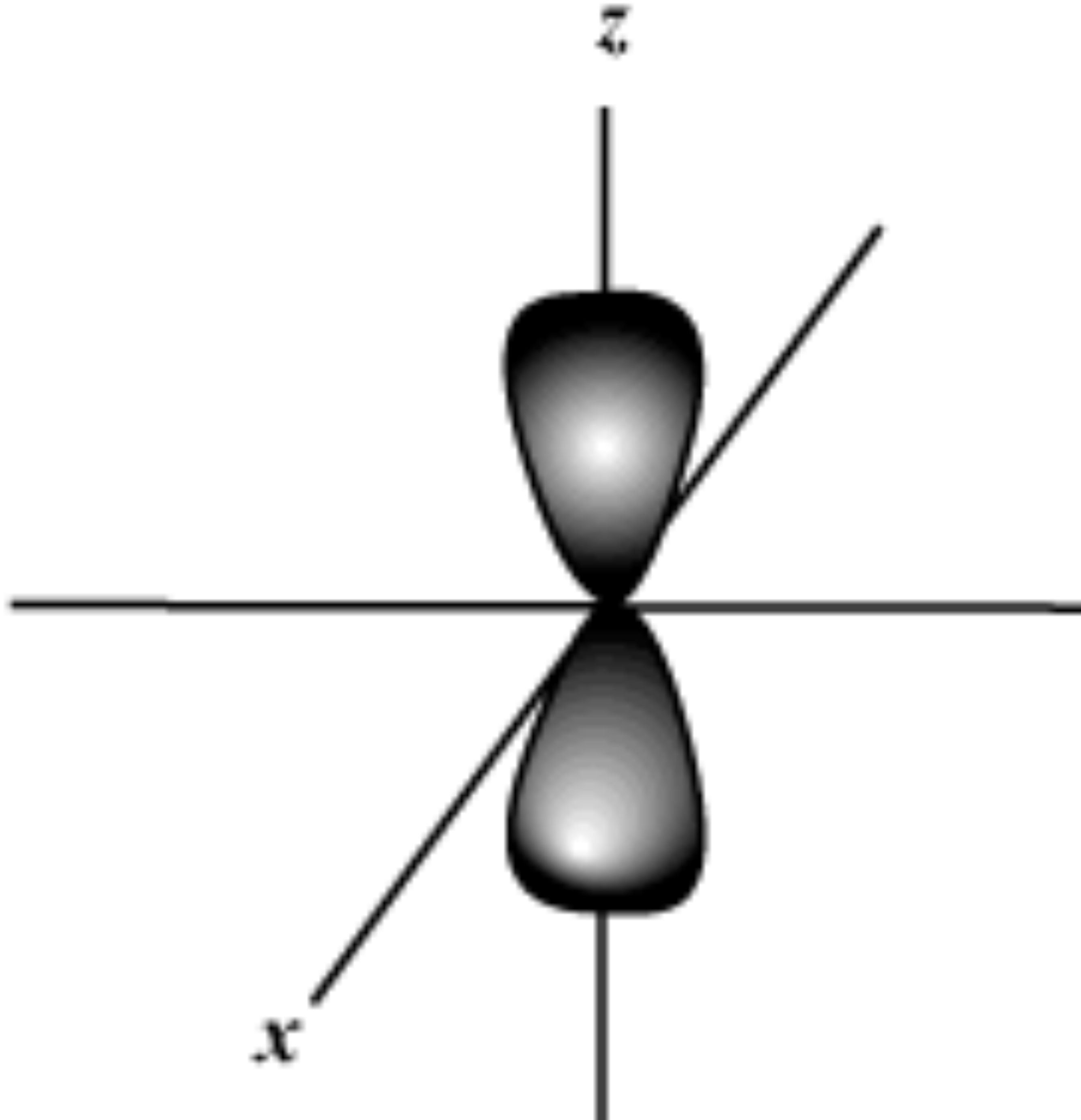
S orbitals are spherical in shape and holds only 2 e^- total.

p-Orbitals



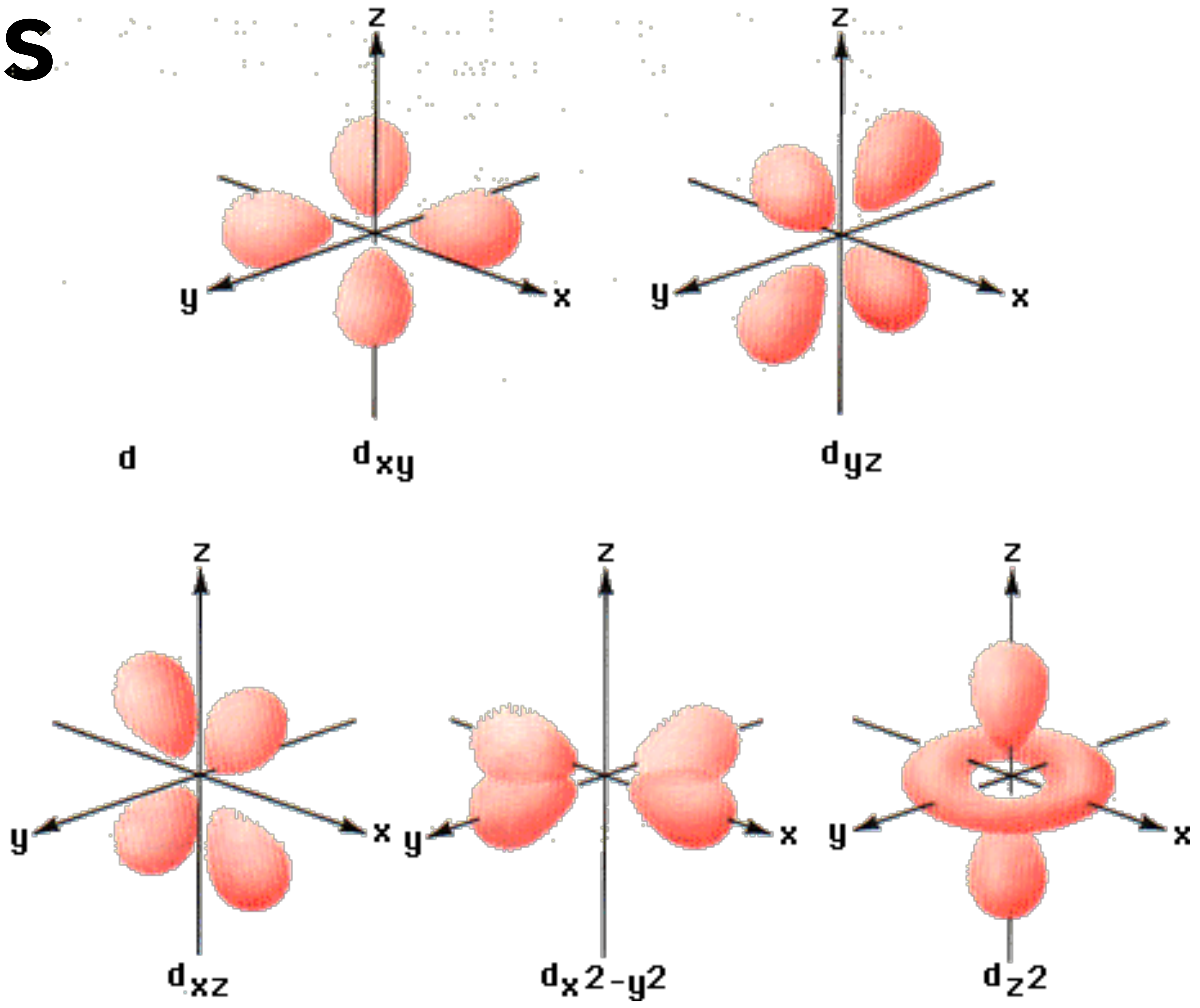
- (*x*, *y*, *z*) are dumbbell shaped
- Each holds 2 e^-
- hold up to 6 e^- total





d-Orbitals

- 4-leaf clover shaped
- 5 types of d-orbitals; each holding 2 electrons
- total of 10 e-'s



Subshells

n **= 1** contains one subshell - **1s**

(1s can hold a maximum of 2 electrons)

n **= 2** contains two subshells - **2s** and **2p**

(2s can hold a maximum of 2 electrons)

(2p can hold a maximum of 6 electrons)

n **= 3** contains 3 subshells - **3s**, **3p** and **3d**

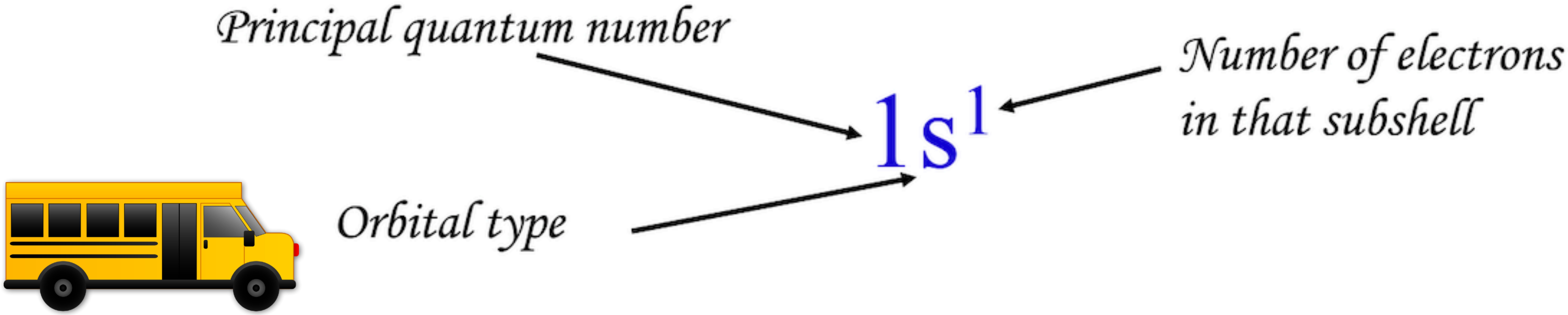
(3s can hold a maximum of 2 electrons)

(3p can hold a maximum of 6 electrons)

(3d can hold a maximum of 10 electrons)

Filling Orbitals with Electrons - *Hund's Rule*

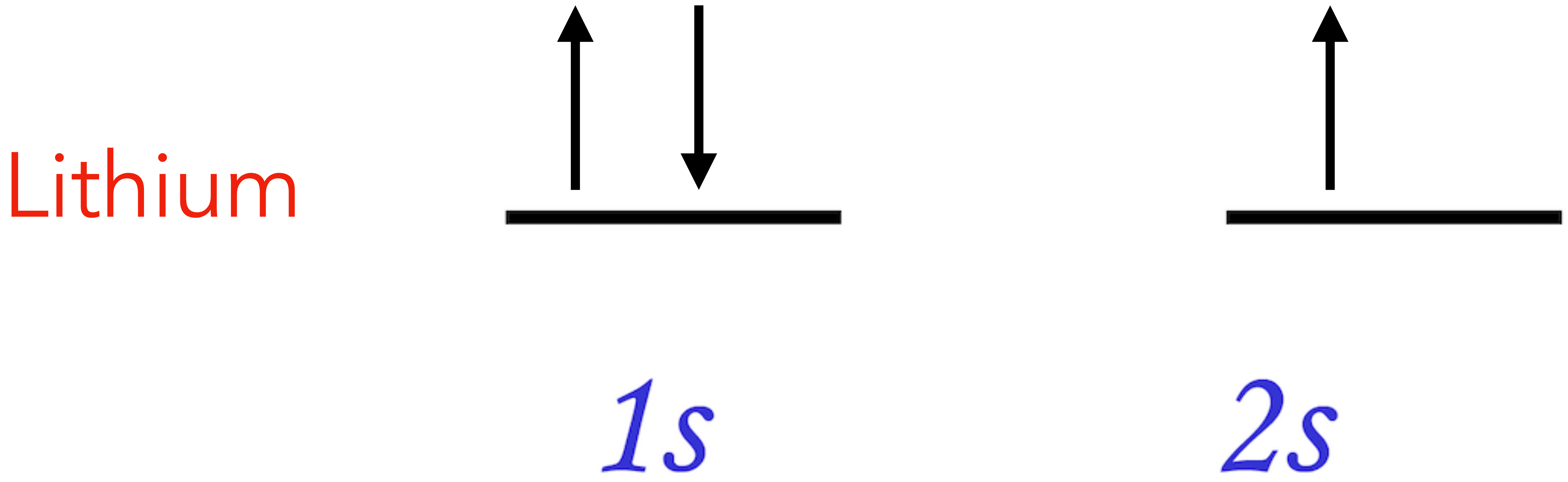
- Sub-shells (s, p, d) are most stable when they are half full or completely filled with electrons.
- Electrons fill orbitals one electron at a time (because they repel) from lowest energy to highest energy level.
- All seats get filled with one person each first, then they double up.



Aufbau Principle - Orbital Filling

- Each orbital can hold a maximum of 2 electrons that will spin in opposite directions.

- Hund’s Rule - When you have more than one orbital in a sub shell (including p, d and f subshells), a single spin up electron is aded to each orbital before you start adding spin down electrons.

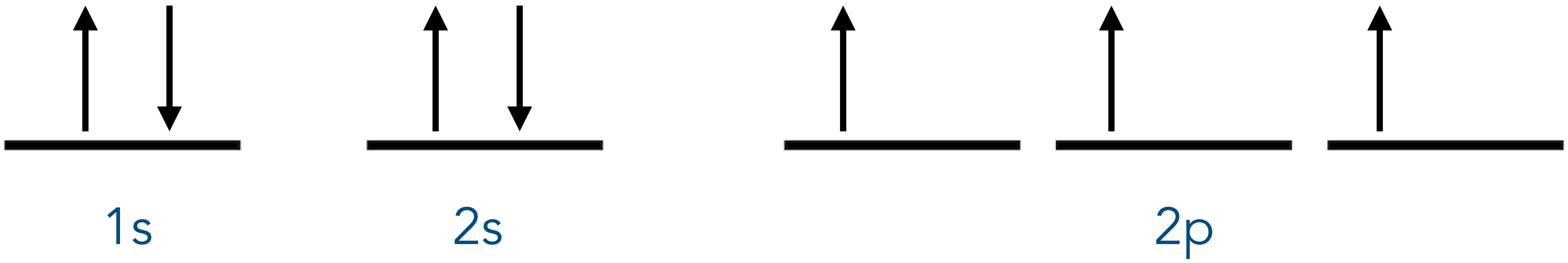


Lithium

1s

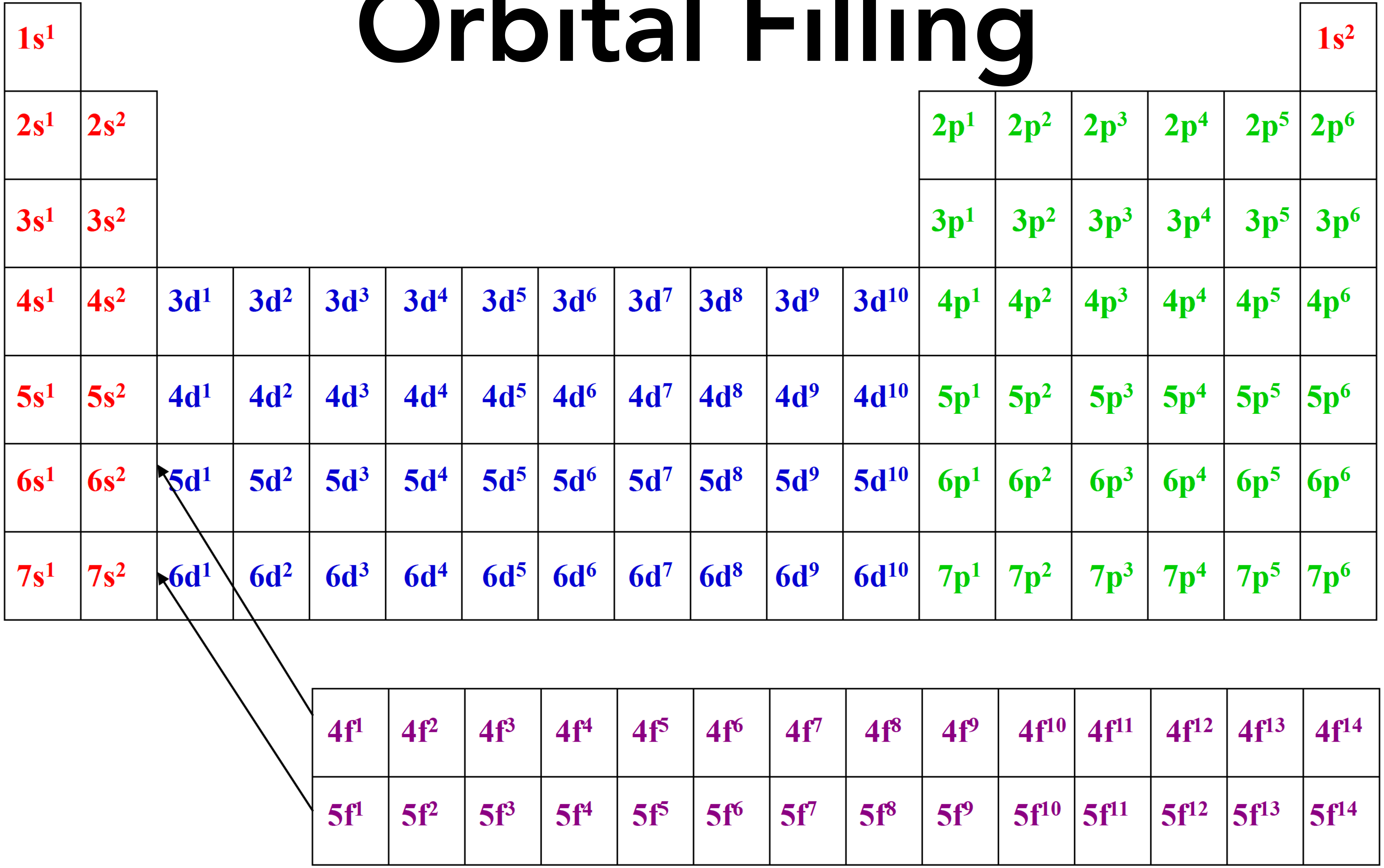
2s

Nitrogen’s Orbital Notation



- Place one unpaired electron in each degenerate (same energy level) orbital that all spin in the same direction before adding electrons that spin in the opposite direction.
- Lower energy system.

Orbital Filling

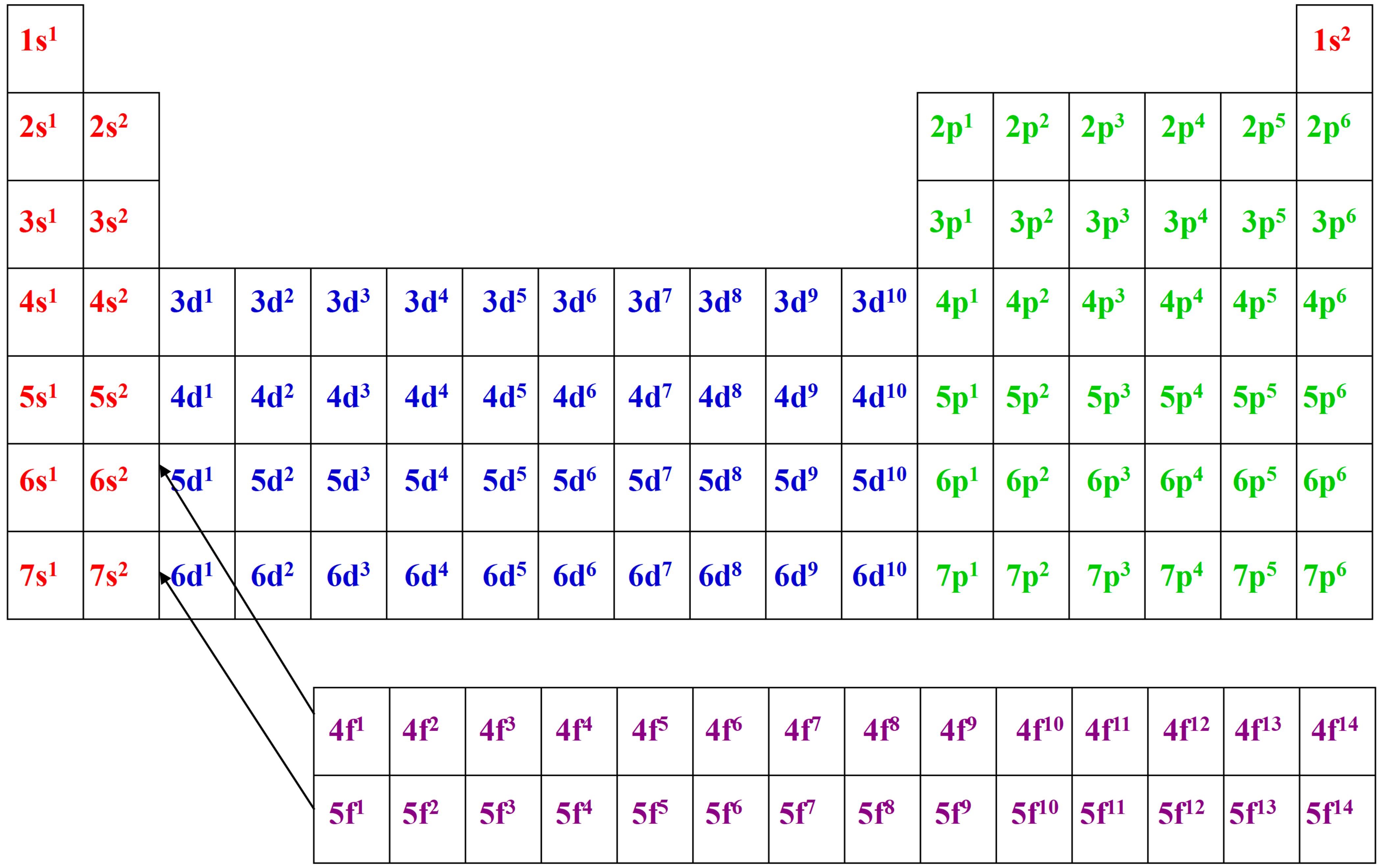


$1s^1$																	$1s^2$
$2s^1$	$2s^2$											$2p^1$	$2p^2$	$2p^3$	$2p^4$	$2p^5$	$2p^6$
$3s^1$	$3s^2$											$3p^1$	$3p^2$	$3p^3$	$3p^4$	$3p^5$	$3p^6$
$4s^1$	$4s^2$	$3d^1$	$3d^2$	$3d^3$	$3d^4$	$3d^5$	$3d^6$	$3d^7$	$3d^8$	$3d^9$	$3d^{10}$	$4p^1$	$4p^2$	$4p^3$	$4p^4$	$4p^5$	$4p^6$
$5s^1$	$5s^2$	$4d^1$	$4d^2$	$4d^3$	$4d^4$	$4d^5$	$4d^6$	$4d^7$	$4d^8$	$4d^9$	$4d^{10}$	$5p^1$	$5p^2$	$5p^3$	$5p^4$	$5p^5$	$5p^6$
$6s^1$	$6s^2$	$5d^1$	$5d^2$	$5d^3$	$5d^4$	$5d^5$	$5d^6$	$5d^7$	$5d^8$	$5d^9$	$5d^{10}$	$6p^1$	$6p^2$	$6p^3$	$6p^4$	$6p^5$	$6p^6$
$7s^1$	$7s^2$	$6d^1$	$6d^2$	$6d^3$	$6d^4$	$6d^5$	$6d^6$	$6d^7$	$6d^8$	$6d^9$	$6d^{10}$	$7p^1$	$7p^2$	$7p^3$	$7p^4$	$7p^5$	$7p^6$

$4f^1$	$4f^2$	$4f^3$	$4f^4$	$4f^5$	$4f^6$	$4f^7$	$4f^8$	$4f^9$	$4f^{10}$	$4f^{11}$	$4f^{12}$	$4f^{13}$	$4f^{14}$
$5f^1$	$5f^2$	$5f^3$	$5f^4$	$5f^5$	$5f^6$	$5f^7$	$5f^8$	$5f^9$	$5f^{10}$	$5f^{11}$	$5f^{12}$	$5f^{13}$	$5f^{14}$

Filling Orbitals (Examples)

- Boron → $1s^2 2s^2 2p^1$ or [He]$2p^1$ (using noble gas abbreviation)
- Carbon → $1s^2 2s^2 2p^2$ or [He]$2p^2$ (no longer using 2-4)
- Nitrogen →
- Oxygen →
- Fluorine →
- Neon →
- Sodium →



$1s^1$																	$1s^2$
$2s^1$	$2s^2$											$2p^1$	$2p^2$	$2p^3$	$2p^4$	$2p^5$	$2p^6$
$3s^1$	$3s^2$											$3p^1$	$3p^2$	$3p^3$	$3p^4$	$3p^5$	$3p^6$
$4s^1$	$4s^2$	$3d^1$	$3d^2$	$3d^3$	$3d^4$	$3d^5$	$3d^6$	$3d^7$	$3d^8$	$3d^9$	$3d^{10}$	$4p^1$	$4p^2$	$4p^3$	$4p^4$	$4p^5$	$4p^6$
$5s^1$	$5s^2$	$4d^1$	$4d^2$	$4d^3$	$4d^4$	$4d^5$	$4d^6$	$4d^7$	$4d^8$	$4d^9$	$4d^{10}$	$5p^1$	$5p^2$	$5p^3$	$5p^4$	$5p^5$	$5p^6$
$6s^1$	$6s^2$	$5d^1$	$5d^2$	$5d^3$	$5d^4$	$5d^5$	$5d^6$	$5d^7$	$5d^8$	$5d^9$	$5d^{10}$	$6p^1$	$6p^2$	$6p^3$	$6p^4$	$6p^5$	$6p^6$
$7s^1$	$7s^2$	$6d^1$	$6d^2$	$6d^3$	$6d^4$	$6d^5$	$6d^6$	$6d^7$	$6d^8$	$6d^9$	$6d^{10}$	$7p^1$	$7p^2$	$7p^3$	$7p^4$	$7p^5$	$7p^6$

$4f^1$	$4f^2$	$4f^3$	$4f^4$	$4f^5$	$4f^6$	$4f^7$	$4f^8$	$4f^9$	$4f^{10}$	$4f^{11}$	$4f^{12}$	$4f^{13}$	$4f^{14}$
$5f^1$	$5f^2$	$5f^3$	$5f^4$	$5f^5$	$5f^6$	$5f^7$	$5f^8$	$5f^9$	$5f^{10}$	$5f^{11}$	$5f^{12}$	$5f^{13}$	$5f^{14}$

Electron Configurations of Ions

- Na → $1s^22s^22p^63s^1$ or [Ne]3s1
- Na^+ → $1s^22s^22p^6$ or [Ne]

- Cl → $1s^22s^22p^63s^23p^5$ or $[Ne]3p^5$
- Cl^- → $1s^22s^22p^63s^23p^6$ or $[Ne]3p^6$

Ions are elements that have lost or gained valence electrons to acquire the electron configurations of noble gases.

Isoelectronic Species

Write the electron configurations for the following (Ar, Cl^-, S^{2-}, Ca^{2+}, and K^+

- Isoelectronic species share the same electronic configurations, but have different radii.
- As the ratio of protons to electrons increases, the forces of attractions on those electrons increases.

d-block Cations

- These elements lose electrons from their highest sublevel first before losing from their d-sublevel.

Iron

- Fe [Ar] $4s^2 3d^6$
- Fe^{2+} [Ar] $3d^6$ (lost two electrons from 4s)
- Fe^{3+} [Ar] $3d^5$ (lost two electrons from 4s and one from 3d)

1.7 Periodic Trends

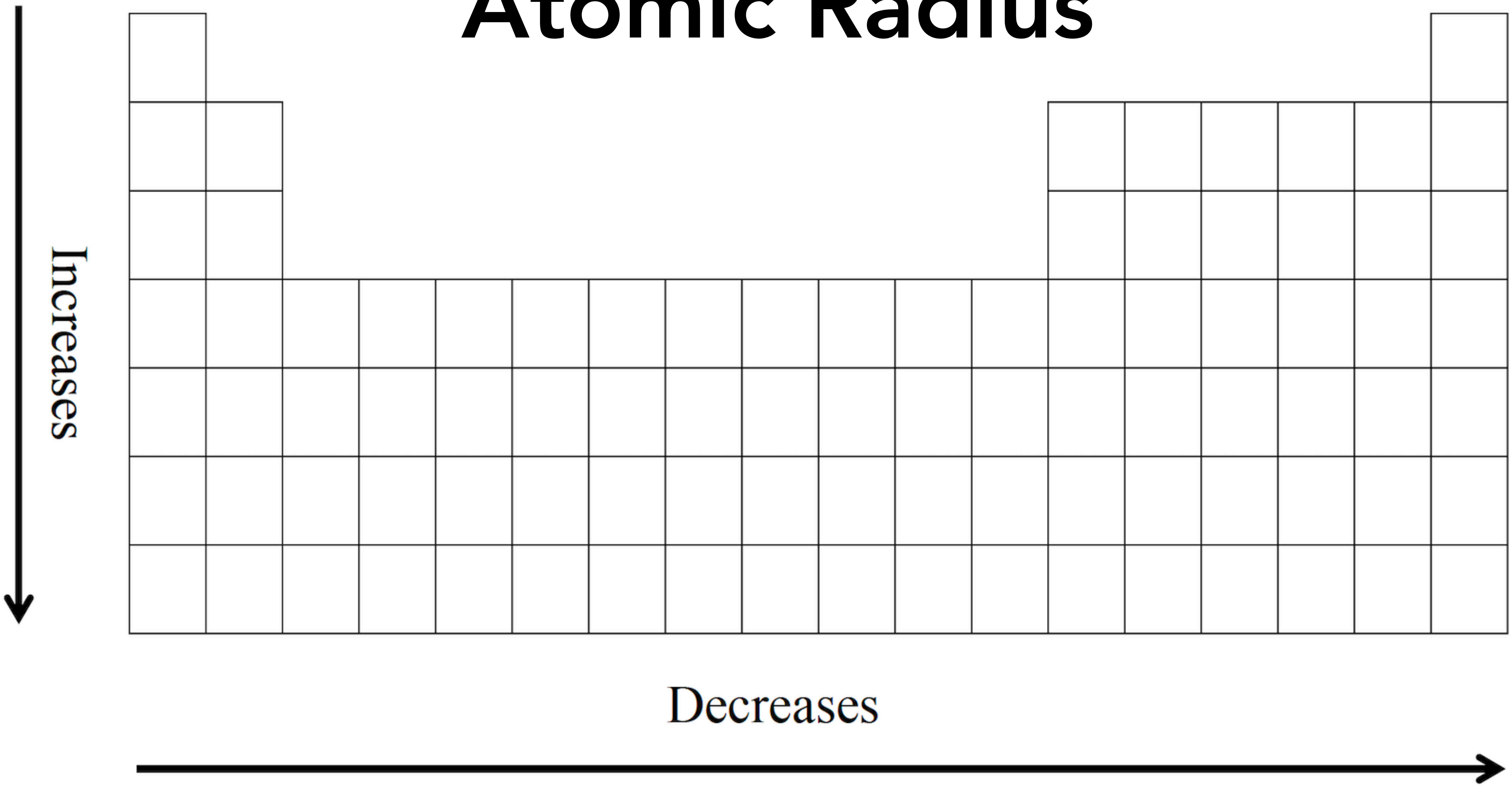
Atomic & Ionic Radii

Ionization Energy

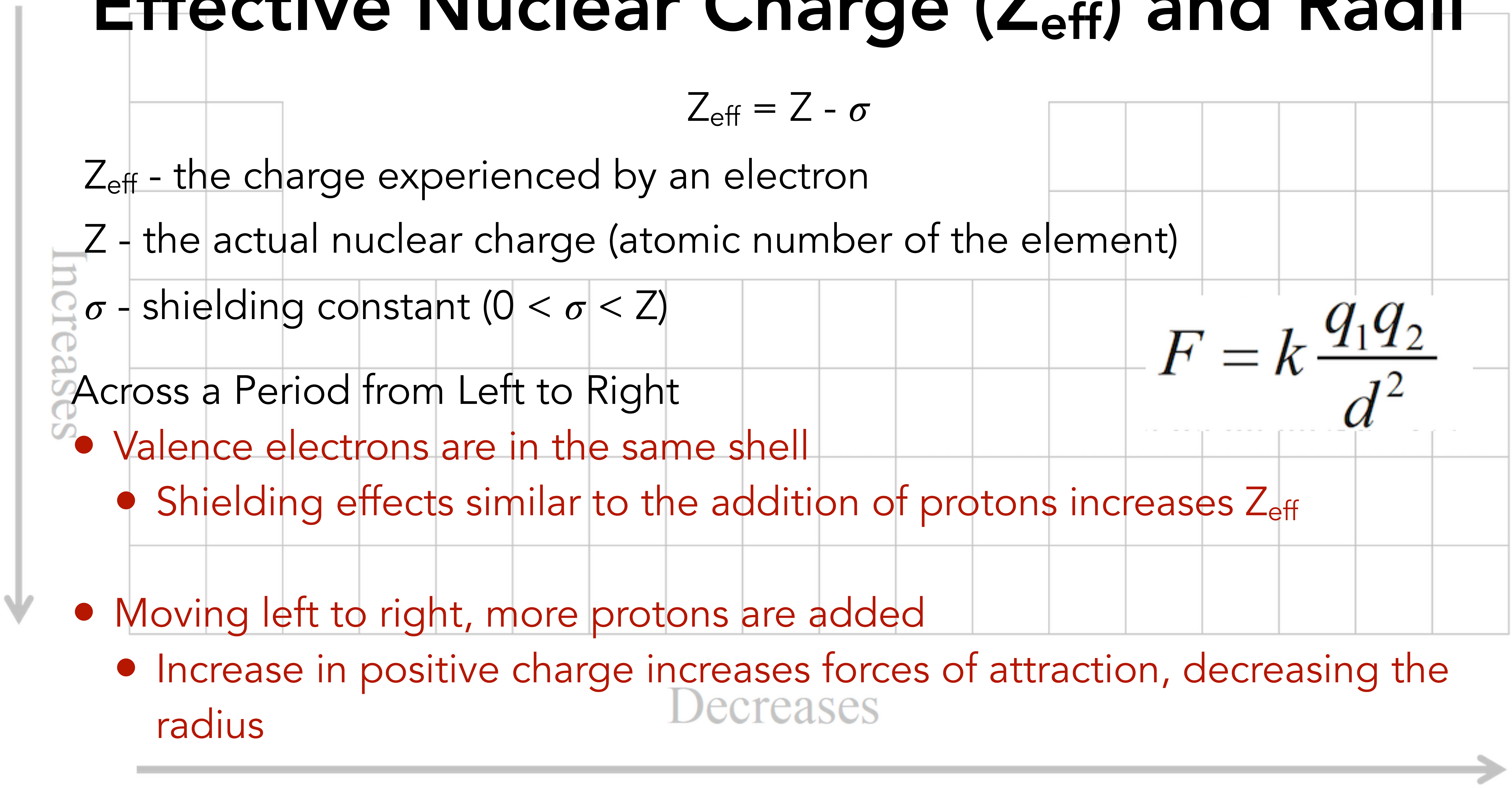
Electron Affinity

Electronegativity

Atomic Radius



Effective Nuclear Charge (Z_{eff}) and Radii



$$Z_{eff} = Z - \sigma$$

Z_{eff} - the charge experienced by an electron

Z - the actual nuclear charge (atomic number of the element)

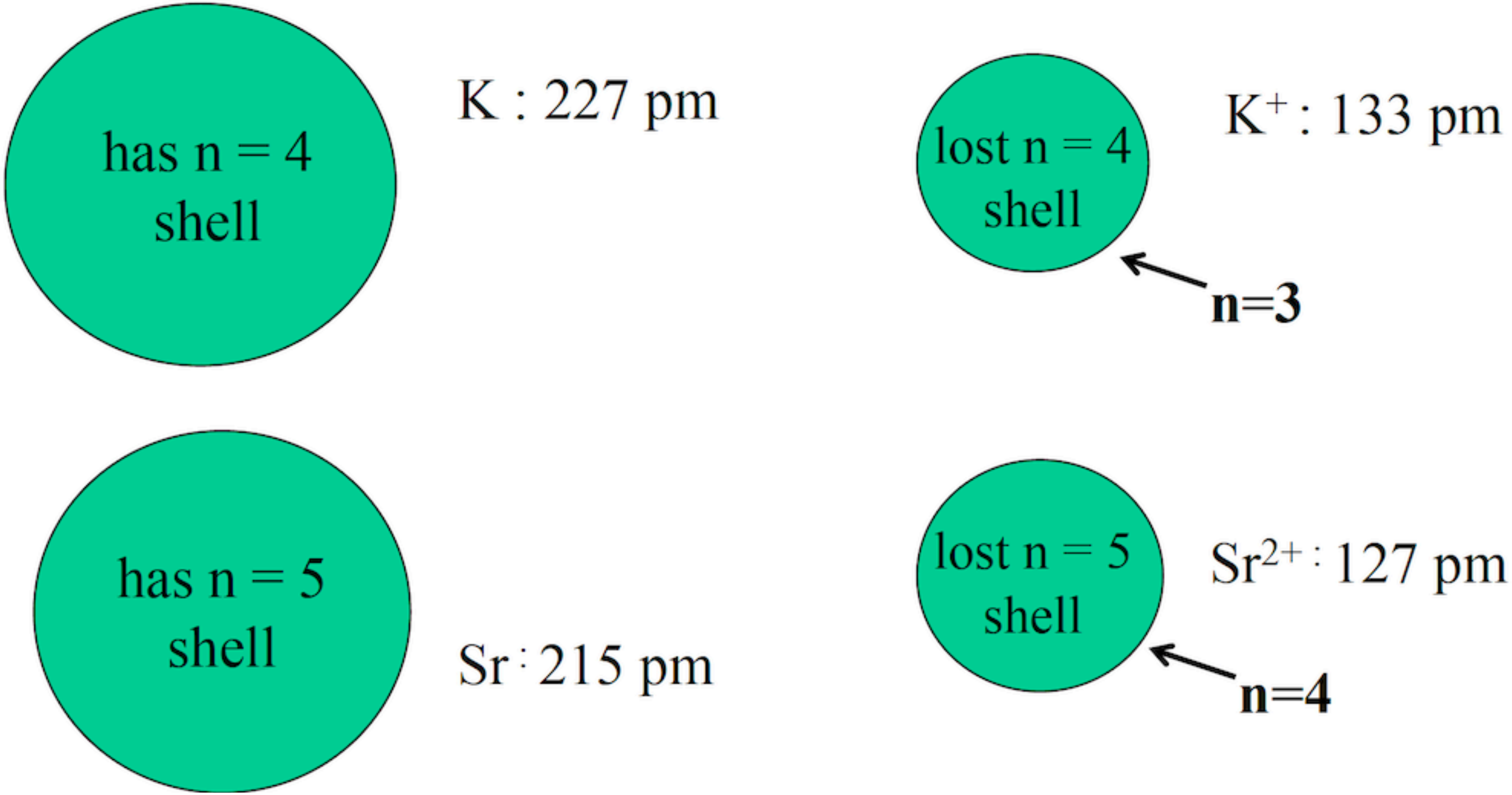
σ - shielding constant ($0 < \sigma < Z$)

$$F = k\frac{q_1 q_2}{d^2}$$

Across a Period from Left to Right

- Valence electrons are in the same shell
  - Shielding effects similar to the addition of protons increases Z_{eff}
- Moving left to right, more protons are added
  - Increase in positive charge increases forces of attraction, decreasing the radius

Ionic Radius



has n = 4 shell

K : 227 pm

lost n = 4 shell

K^+ : 133 pm

n=3

has n = 5 shell

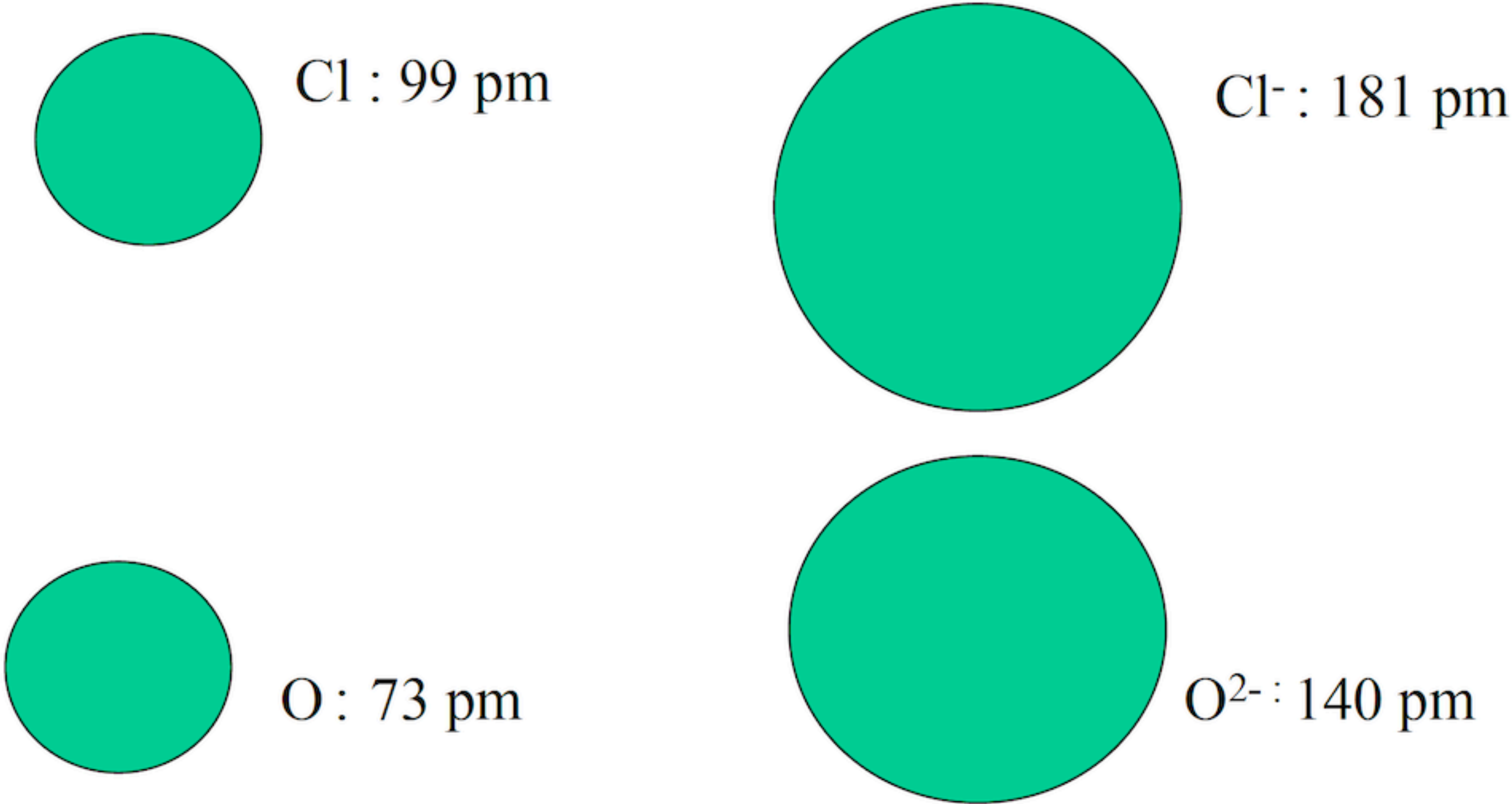
Sr : 215 pm

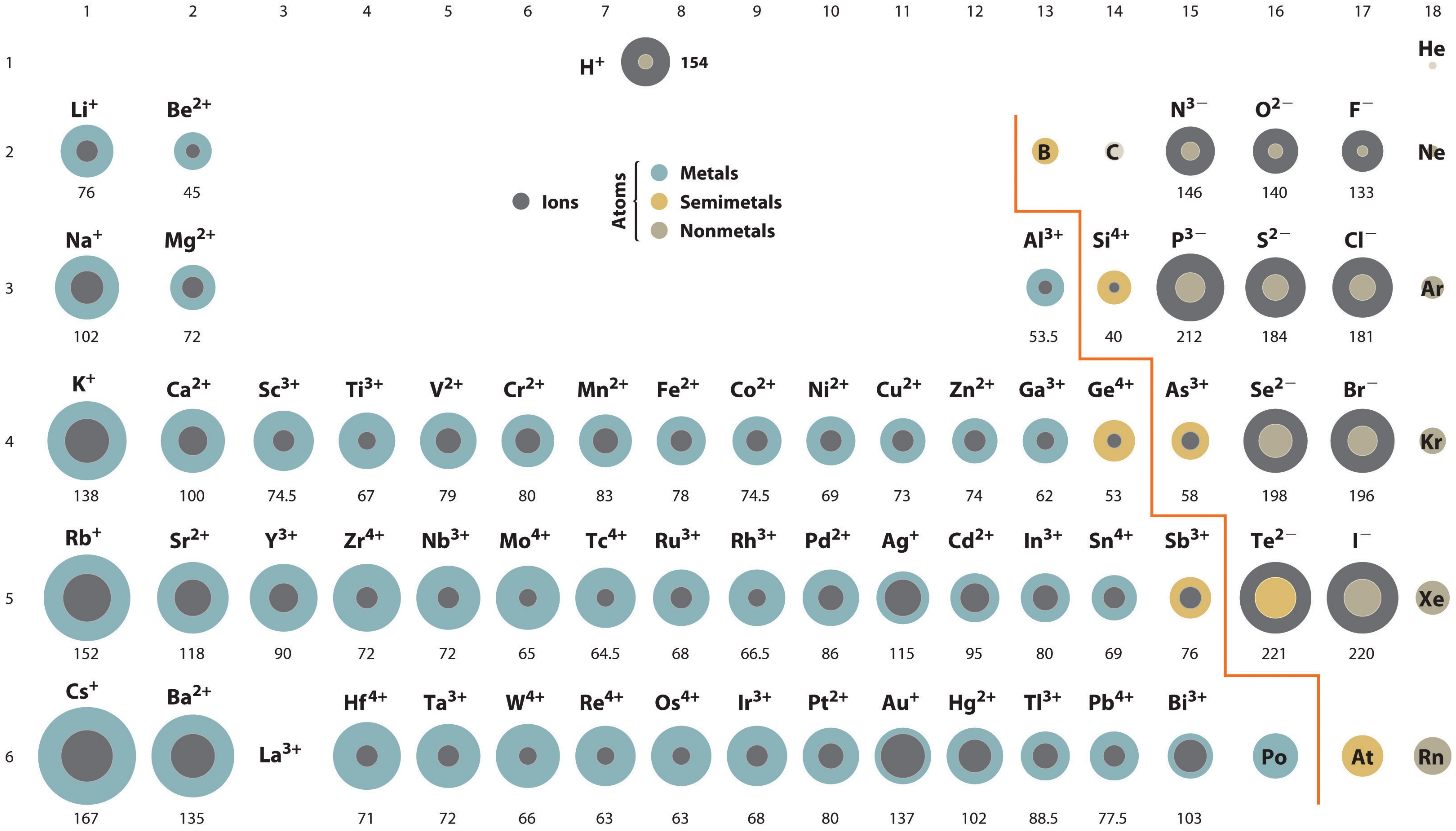
lost n = 5 shell

Sr^{2+} : 127 pm

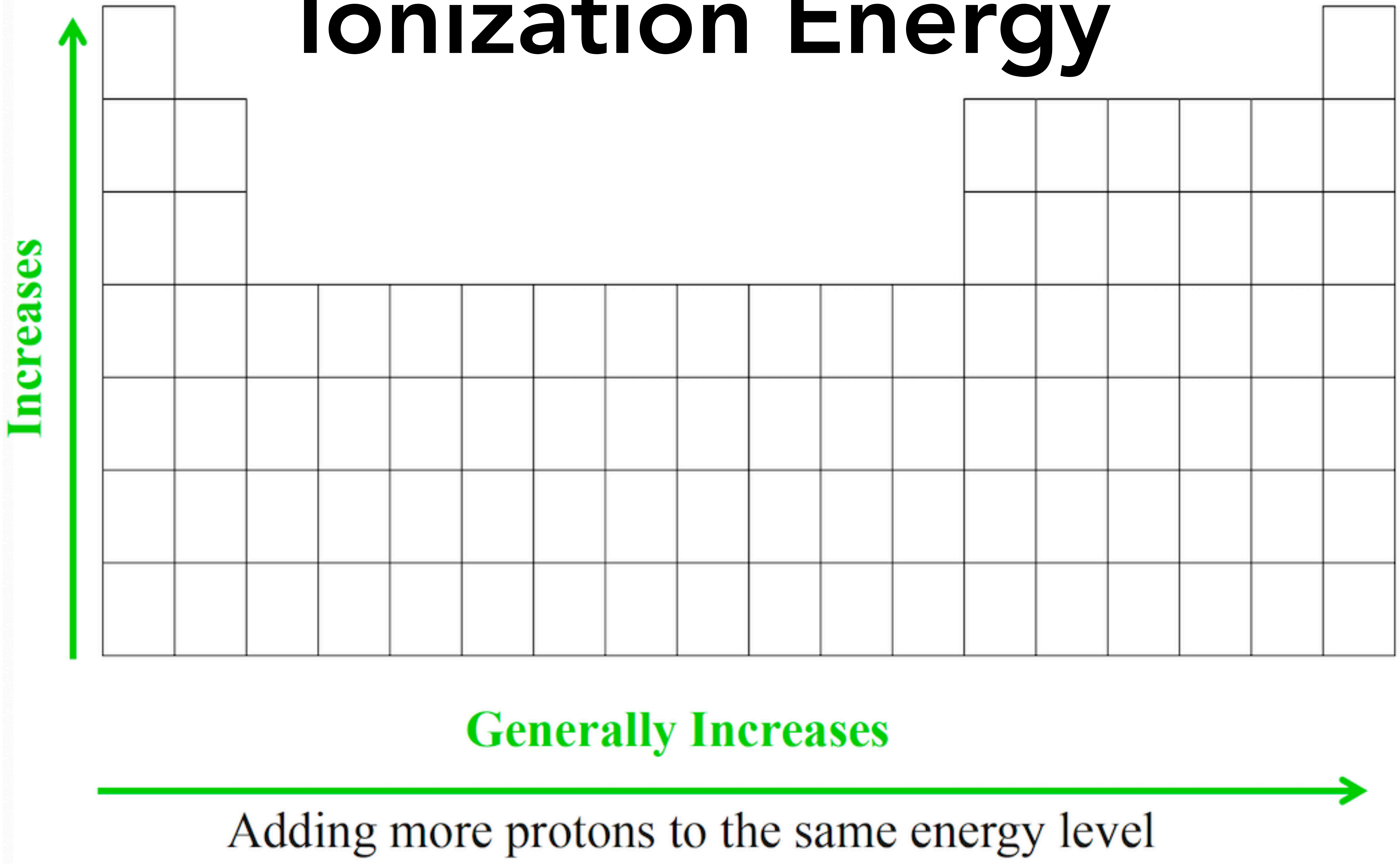
n=4

Ionic Radius




1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
H+ 154
He
2
Li+ 76
Be2+ 45
B
C
N3− 146
O2− 140
F− 133
Ne
Ions
Atoms
Metals
Semimetals
Nonmetals
3
Na+ 102
Mg2+ 72
Al3+ 53.5
Si4+ 40
P3− 212
S2− 184
Cl− 181
Ar
4
K+ 138
Ca2+ 100
Sc3+ 74.5
Ti3+ 67
V2+ 79
Cr2+ 80
Mn2+ 83
Fe2+ 78
Co2+ 74.5
Ni2+ 69
Cu2+ 73
Zn2+ 74
Ga3+ 62
Ge4+ 53
As3+ 58
Se2− 198
Br− 196
Kr
5
Rb+ 152
Sr2+ 118
Y3+ 90
Zr4+ 72
Nb3+ 72
Mo4+ 65
Tc4+ 64.5
Ru3+ 68
Rh3+ 66.5
Pd2+ 86
Ag+ 115
Cd2+ 95
In3+ 80
Sn4+ 69
Sb3+ 76
Te2− 221
I− 220
Xe
6
Cs+ 167
Ba2+ 135
La3+
Hf4+ 71
Ta3+ 72
W4+ 66
Re4+ 63
Os4+ 63
Ir3+ 68
Pt2+ 80
Au+ 137
Hg2+ 102
Tl3+ 88.5
Pb4+ 77.5
Bi3+ 103
Po
At
Rn

Ionization Energy



Ionization Energy

- **2nd ionization potential will always be larger.**
  - Radius reduced after first electron removed, increasing the ratio of protons to electrons.
- **All elements have one extremely large increase in ionization energy**
  - When electron configuration drops a principal quantum number (n=5 to n=4), which causes a more drastic decrease in radius.

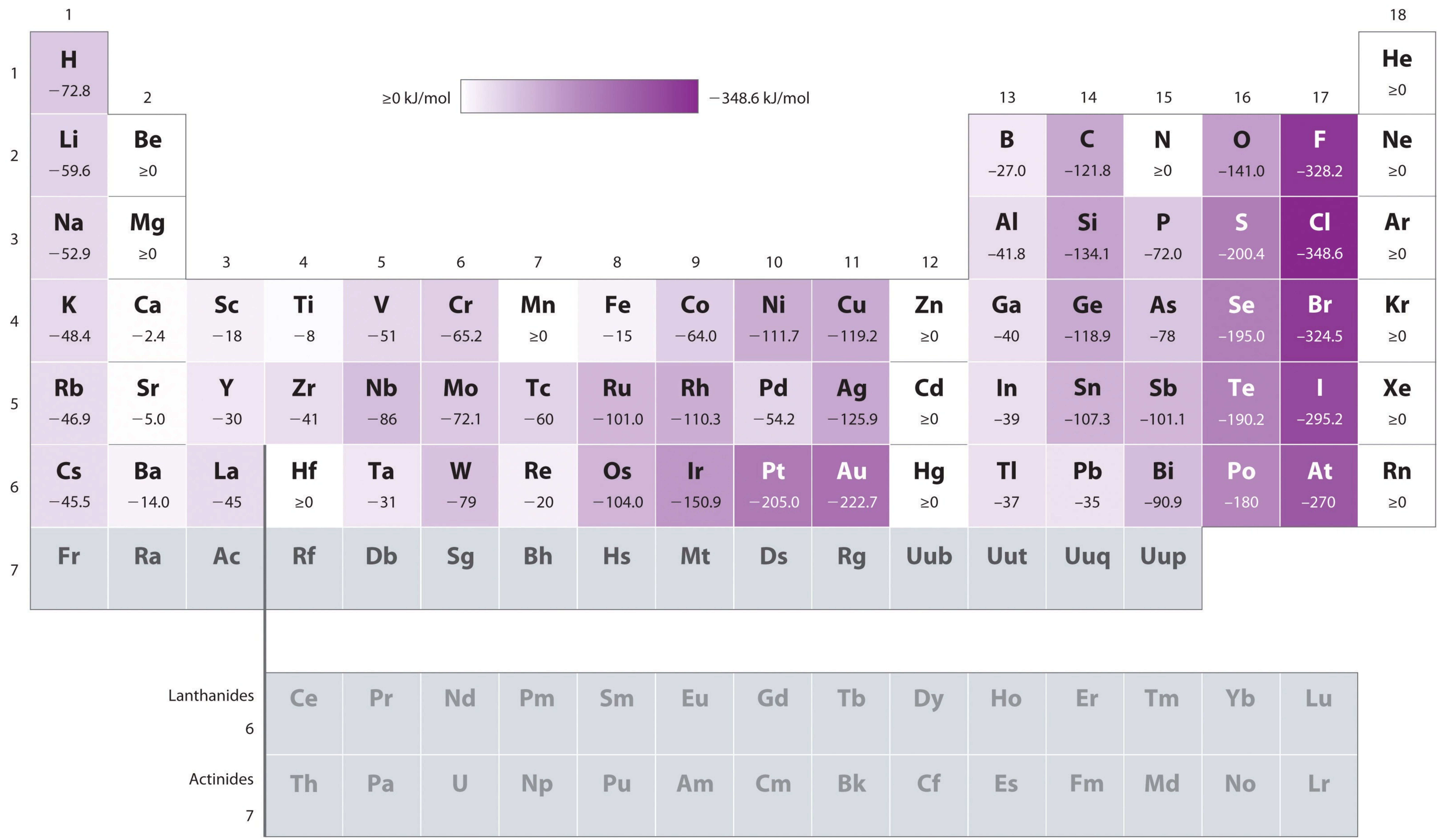
Electron Affinity

- Energy change that occurs when an electron is added to a gaseous atom to form a negative ion.

- Measure of how much an elements wants to accept another electron.

- Negative value (exothermic)
  - Wants to accept the electron

- Positive value (endothermic)
  - Does not want to accept the electrons



≥0 kJ/mol ▨ −348.6 kJ/mol

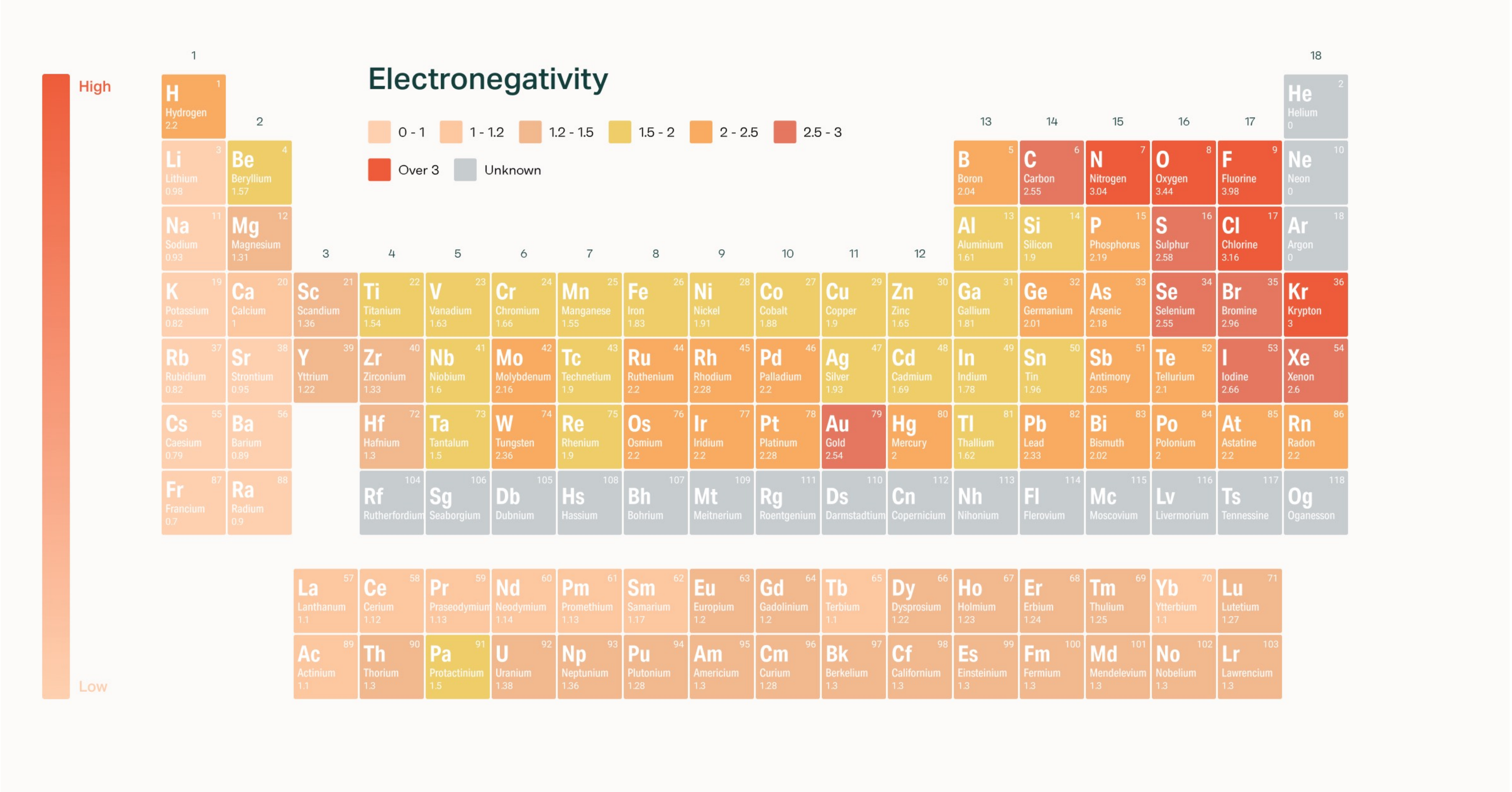
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	**H** −72.8																	**He** ≥0
2	**Li** −59.6	**Be** ≥0											**B** −27.0	**C** −121.8	**N** ≥0	**O** −141.0	**F** −328.2	**Ne** ≥0
3	**Na** −52.9	**Mg** ≥0											**Al** −41.8	**Si** −134.1	**P** −72.0	**S** −200.4	**Cl** −348.6	**Ar** ≥0
4	**K** −48.4	**Ca** −2.4	**Sc** −18	**Ti** −8	**V** −51	**Cr** −65.2	**Mn** ≥0	**Fe** −15	**Co** −64.0	**Ni** −111.7	**Cu** −119.2	**Zn** ≥0	**Ga** −40	**Ge** −118.9	**As** −78	**Se** −195.0	**Br** −324.5	**Kr** ≥0
5	**Rb** −46.9	**Sr** −5.0	**Y** −30	**Zr** −41	**Nb** −86	**Mo** −72.1	**Tc** −60	**Ru** −101.0	**Rh** −110.3	**Pd** −54.2	**Ag** −125.9	**Cd** ≥0	**In** −39	**Sn** −107.3	**Sb** −101.1	**Te** −190.2	**I** −295.2	**Xe** ≥0
6	**Cs** −45.5	**Ba** −14.0	**La** −45	**Hf** ≥0	**Ta** −31	**W** −79	**Re** −20	**Os** −104.0	**Ir** −150.9	**Pt** −205.0	**Au** −222.7	**Hg** ≥0	**Tl** −37	**Pb** −35	**Bi** −90.9	**Po** −180	**At** −270	**Rn** ≥0
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup			
Lanthanides 6				Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
Actinides 7				Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

Electron Affinity

- **Down a Group (top to bottom)**
  - New shells added with larger orbitals
  - <u>E_A values generally decrease</u> because the force of attraction between the nucleus and the added electron is weaker.
- **Left to Right across a Period**
  - Effective nuclear charge increases
  - More protons are added, decreasing atomic radii
  - <u>E_A values generally increase</u>

Electronegativity

- Element's ability to attract electrons in a chemical bond.
- Electron density higher around more electronegative elements in a chemical bond.

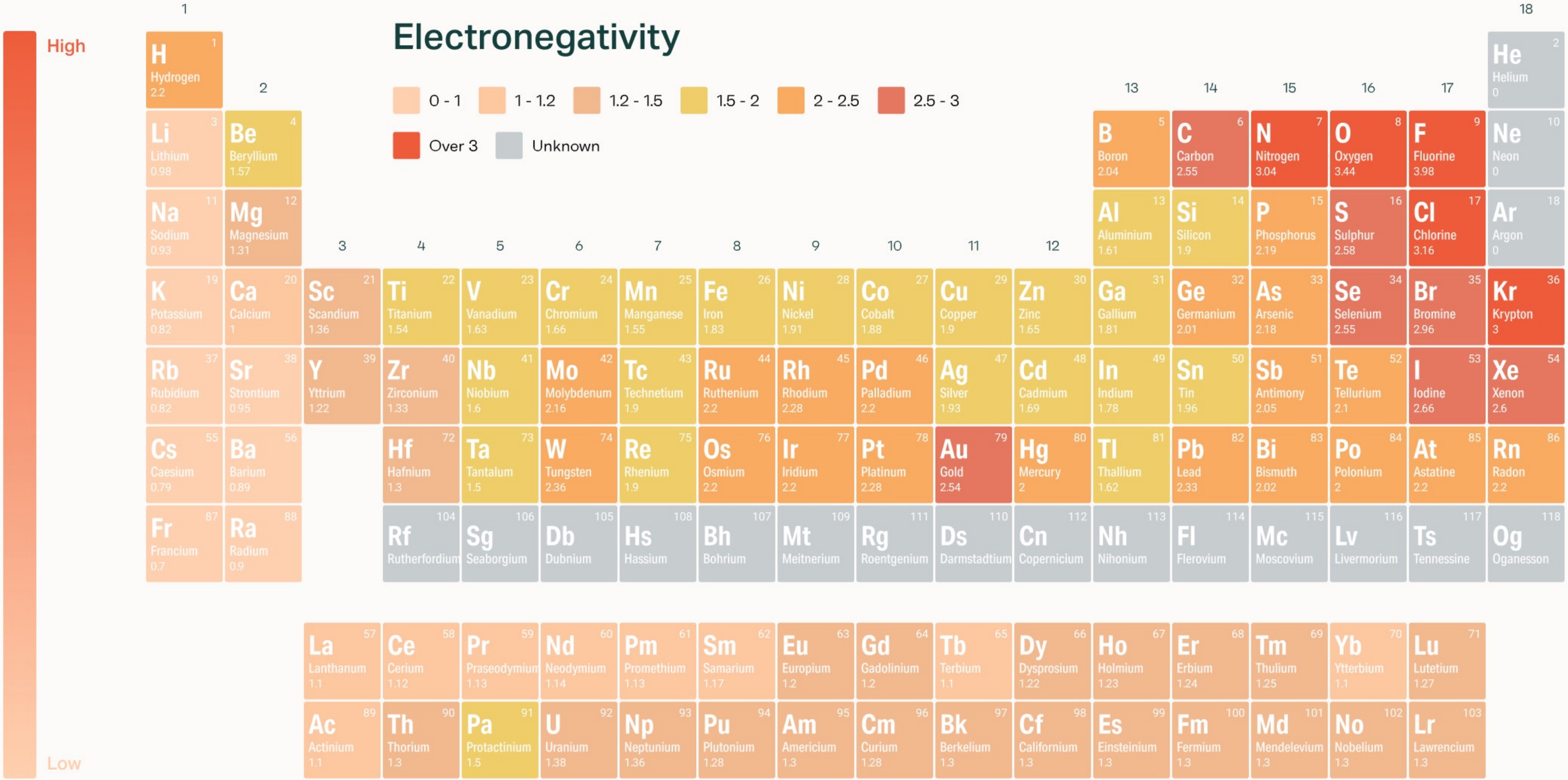


Electronegativity

0 - 1
1 - 1.2
1.2 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
Over 3
Unknown

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 1 Hydrogen 2.2																	He 2 Helium 0
Li 3 Lithium 0.98	Be 4 Beryllium 1.57											B 5 Boron 2.04	C 6 Carbon 2.55	N 7 Nitrogen 3.04	O 8 Oxygen 3.44	F 9 Fluorine 3.98	Ne 10 Neon 0
Na 11 Sodium 0.93	Mg 12 Magnesium 1.31											Al 13 Aluminium 1.61	Si 14 Silicon 1.9	P 15 Phosphorus 2.19	S 16 Sulphur 2.58	Cl 17 Chlorine 3.16	Ar 18 Argon 0
K 19 Potassium 0.82	Ca 20 Calcium 1	Sc 21 Scandium 1.36	Ti 22 Titanium 1.54	V 23 Vanadium 1.63	Cr 24 Chromium 1.66	Mn 25 Manganese 1.55	Fe 26 Iron 1.83	Ni 28 Nickel 1.91	Co 27 Cobalt 1.88	Cu 29 Copper 1.9	Zn 30 Zinc 1.65	Ga 31 Gallium 1.81	Ge 32 Germanium 2.01	As 33 Arsenic 2.18	Se 34 Selenium 2.55	Br 35 Bromine 2.96	Kr 36 Krypton 3
Rb 37 Rubidium 0.82	Sr 38 Strontium 0.95	Y 39 Yttrium 1.22	Zr 40 Zirconium 1.33	Nb 41 Niobium 1.6	Mo 42 Molybdenum 2.16	Tc 43 Technetium 1.9	Ru 44 Ruthenium 2.2	Rh 45 Rhodium 2.28	Pd 46 Palladium 2.2	Ag 47 Silver 1.93	Cd 48 Cadmium 1.69	In 49 Indium 1.78	Sn 50 Tin 1.96	Sb 51 Antimony 2.05	Te 52 Tellurium 2.1	I 53 Iodine 2.66	Xe 54 Xenon 2.6
Cs 55 Caesium 0.79	Ba 56 Barium 0.89		Hf 72 Hafnium 1.3	Ta 73 Tantalum 1.5	W 74 Tungsten 2.36	Re 75 Rhenium 1.9	Os 76 Osmium 2.2	Ir 77 Iridium 2.2	Pt 78 Platinum 2.28	Au 79 Gold 2.54	Hg 80 Mercury 2	Tl 81 Thallium 1.62	Pb 82 Lead 2.33	Bi 83 Bismuth 2.02	Po 84 Polonium 2	At 85 Astatine 2.2	Rn 86 Radon 2.2
Fr 87 Francium 0.7	Ra 88 Radium 0.9		Rf 104 Rutherfordium	Sg 106 Seaborgium	Db 105 Dubnium	Hs 108 Hassium	Bh 107 Bohrium	Mt 109 Meitnerium	Rg 111 Roentgenium	Ds 110 Darmstadtium	Cn 112 Copernicium	Nh 113 Nihonium	Fl 114 Flerovium	Mc 115 Moscovium	Lv 116 Livermorium	Ts 117 Tennessine	Og 118 Oganesson
		La 57 Lanthanum 1.1	Ce 58 Cerium 1.12	Pr 59 Praseodymium 1.13	Nd 60 Neodymium 1.14	Pm 61 Promethium 1.13	Sm 62 Samarium 1.17	Eu 63 Europium 1.2	Gd 64 Gadolinium 1.2	Tb 65 Terbium 1.1	Dy 66 Dysprosium 1.22	Ho 67 Holmium 1.23	Er 68 Erbium 1.24	Tm 69 Thulium 1.25	Yb 70 Ytterbium 1.1	Lu 71 Lutetium 1.27	
		Ac 89 Actinium 1.1	Th 90 Thorium 1.3	Pa 91 Protactinium 1.5	U 92 Uranium 1.38	Np 93 Neptunium 1.36	Pu 94 Plutonium 1.28	Am 95 Americium 1.3	Cm 96 Curium 1.28	Bk 97 Berkelium 1.3	Cf 98 Californium 1.3	Es 99 Einsteinium 1.3	Fm 100 Fermium 1.3	Md 101 Mendelevium 1.3	No 102 Nobelium 1.3	Lr 103 Lawrencium 1.3	

Electronegativity



- 0 - 1
- 1 - 1.2
- 1.2 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- Over 3
- Unknown

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 1 Hydrogen 2.2																	**He** 2 Helium 0
Li 3 Lithium 0.98	**Be** 4 Beryllium 1.57											**B** 5 Boron 2.04	**C** 6 Carbon 2.55	**N** 7 Nitrogen 3.04	**O** 8 Oxygen 3.44	**F** 9 Fluorine 3.98	**Ne** 10 Neon 0
Na 11 Sodium 0.93	**Mg** 12 Magnesium 1.31											**Al** 13 Aluminium 1.61	**Si** 14 Silicon 1.9	**P** 15 Phosphorus 2.19	**S** 16 Sulphur 2.58	**Cl** 17 Chlorine 3.16	**Ar** 18 Argon 0
K 19 Potassium 0.82	**Ca** 20 Calcium 1	**Sc** 21 Scandium 1.36	**Ti** 22 Titanium 1.54	**V** 23 Vanadium 1.63	**Cr** 24 Chromium 1.66	**Mn** 25 Manganese 1.55	**Fe** 26 Iron 1.83	**Ni** 28 Nickel 1.91	**Co** 27 Cobalt 1.88	**Cu** 29 Copper 1.9	**Zn** 30 Zinc 1.65	**Ga** 31 Gallium 1.81	**Ge** 32 Germanium 2.01	**As** 33 Arsenic 2.18	**Se** 34 Selenium 2.55	**Br** 35 Bromine 2.96	**Kr** 36 Krypton 3
Rb 37 Rubidium 0.82	**Sr** 38 Strontium 0.95	**Y** 39 Yttrium 1.22	**Zr** 40 Zirconium 1.33	**Nb** 41 Niobium 1.6	**Mo** 42 Molybdenum 2.16	**Tc** 43 Technetium 1.9	**Ru** 44 Ruthenium 2.2	**Rh** 45 Rhodium 2.28	**Pd** 46 Palladium 2.2	**Ag** 47 Silver 1.93	**Cd** 48 Cadmium 1.69	**In** 49 Indium 1.78	**Sn** 50 Tin 1.96	**Sb** 51 Antimony 2.05	**Te** 52 Tellurium 2.1	**I** 53 Iodine 2.66	**Xe** 54 Xenon 2.6
Cs 55 Caesium 0.79	**Ba** 56 Barium 0.89		**Hf** 72 Hafnium 1.3	**Ta** 73 Tantalum 1.5	**W** 74 Tungsten 2.36	**Re** 75 Rhenium 1.9	**Os** 76 Osmium 2.2	**Ir** 77 Iridium 2.2	**Pt** 78 Platinum 2.28	**Au** 79 Gold 2.54	**Hg** 80 Mercury 2	**Tl** 81 Thallium 1.62	**Pb** 82 Lead 2.33	**Bi** 83 Bismuth 2.02	**Po** 84 Polonium 2	**At** 85 Astatine 2.2	**Rn** 86 Radon 2.2
Fr 87 Francium 0.7	**Ra** 88 Radium 0.9		**Rf** 104 Rutherfordium	**Sg** 106 Seaborgium	**Db** 105 Dubnium	**Hs** 108 Hassium	**Bh** 107 Bohrium	**Mt** 109 Meitnerium	**Rg** 111 Roentgenium	**Ds** 110 Darmstadtium	**Cn** 112 Copernicium	**Nh** 113 Nihonium	**Fl** 114 Flerovium	**Mc** 115 Moscovium	**Lv** 116 Livermorium	**Ts** 117 Tennessine	**Og** 118 Oganesson
		La 57 Lanthanum 1.1	**Ce** 58 Cerium 1.12	**Pr** 59 Praseodymium 1.13	**Nd** 60 Neodymium 1.14	**Pm** 61 Promethium 1.13	**Sm** 62 Samarium 1.17	**Eu** 63 Europium 1.2	**Gd** 64 Gadolinium 1.2	**Tb** 65 Terbium 1.1	**Dy** 66 Dysprosium 1.22	**Ho** 67 Holmium 1.23	**Er** 68 Erbium 1.24	**Tm** 69 Thulium 1.25	**Yb** 70 Ytterbium 1.1	**Lu** 71 Lutetium 1.27	
		Ac 89 Actinium 1.1	**Th** 90 Thorium 1.3	**Pa** 91 Protactinium 1.5	**U** 92 Uranium 1.38	**Np** 93 Neptunium 1.36	**Pu** 94 Plutonium 1.28	**Am** 95 Americium 1.3	**Cm** 96 Curium 1.28	**Bk** 97 Berkelium 1.3	**Cf** 98 Californium 1.3	**Es** 99 Einsteinium 1.3	**Fm** 100 Fermium 1.3	**Md** 101 Mendelevium 1.3	**No** 102 Nobelium 1.3	**Lr** 103 Lawrencium 1.3	