Ionization Energy

- First Ionization energy is the energy required to remove an electron from an atom of an element, producing a cation:

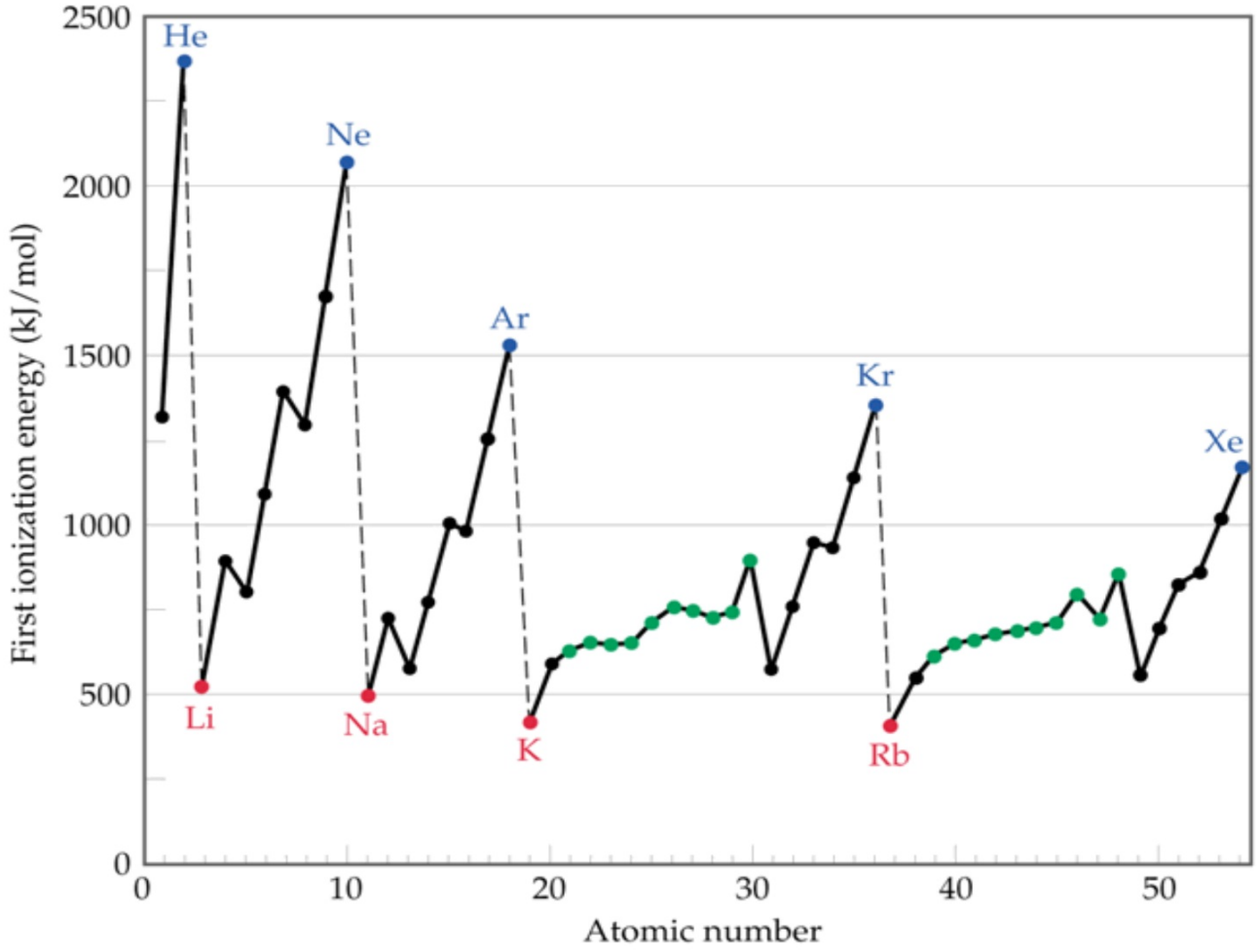
$$M \longrightarrow M^{+} + e^{-}$$

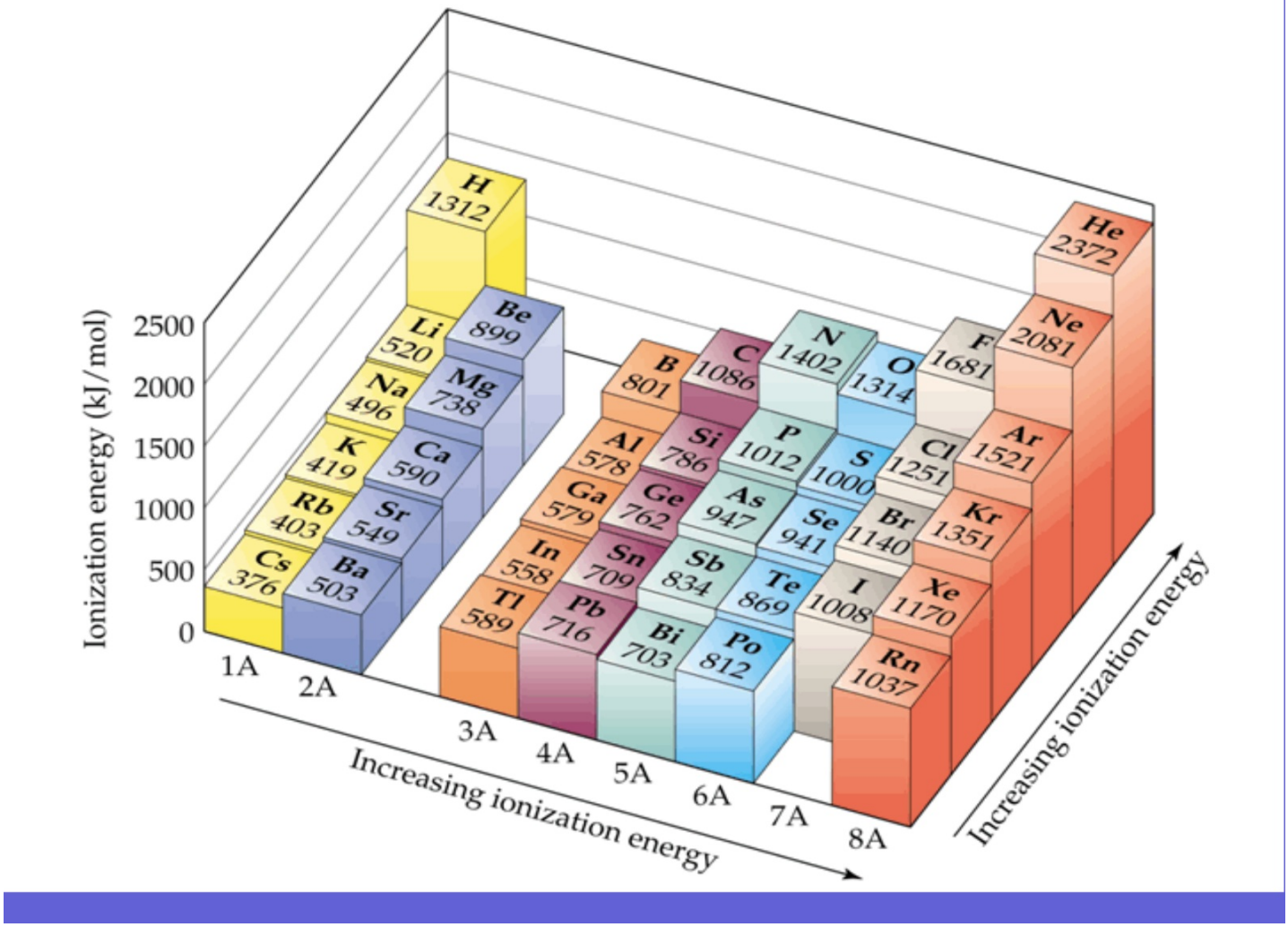
Periodic Trends in Ionization Energies

- Ionization energy decreases down a group.
- This means that the outermost electron is more readily removed as we go down a group.
- As the atom gets bigger, it becomes easier to remove an electron from the most spatially extended orbital.
- Ionization energy generally increases across a period.
- As we move across a period, Z_{eff} increases. Therefore, it becomes more difficult to remove an electron.
- Two exceptions: removing the first *p* electron and removing the fourth *p* electron.

- The *s* electrons are more effective at shielding than *p* electrons. Therefore, forming the s^2p^0 becomes more favorable. (lower than expected first ionization energy for elements in group 13)

- When a second electron is placed in a *p* orbital, the electron-electron repulsion increases. When this electron is removed, the resulting s^2p^3 is more stable than the starting s^2p^4 configuration. Therefore, there is a decrease in ionization energy. (lower than expected first ionization energy for elements in group 16)


2500
2000
1500
1000
500
0
First ionization energy (kJ/mol)
He
Ne
Ar
Kr
Xe
Li
Na
K
Rb
0
10
20
30
40
50
Atomic number


Ionization energy (kJ/mol)
2500
2000
1500
1000
500
0
H 1312
He 2372
Li 520
Be 899
B 801
C 1086
N 1402
O 1314
F 1681
Ne 2081
Na 496
Mg 738
Al 578
Si 786
P 1012
S 1000
Cl 1251
Ar 1521
K 419
Ca 590
Ga 579
Ge 762
As 947
Se 941
Br 1140
Kr 1351
Rb 403
Sr 549
In 558
Sn 709
Sb 834
Te 869
I 1008
Xe 1170
Cs 376
Ba 503
Tl 589
Pb 716
Bi 703
Po 812
Rn 1037
1A
2A
3A
4A
5A
6A
7A
8A
Increasing ionization energy
Increasing ionization energy

Examples – Put each set in order of increasing first ionization energy:

1. P, Cl, Al, Na, S, Mg
2. Ca, Be, Ba, Mg, Sr
3. Ca, F, As, Rb, O, K, S, Ga

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1. Na < Al < Mg < S < P < Cl
2. Ba < Sr < Ca < Mg < Be
3. Rb < K < Ga < Ca < As < S < O < F

Variations in Successive Ionization Energies

- There is a sharp increase in ionization energy when a core electron is removed.

TABLE 7.2 Successive Values of Ionization Energies, I, for the Elements Sodium through Argon (kJ/mol)

Element	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Na	496	4560			(inner-shell electrons)		
Mg	738	1450	7730				
Al	578	1820	2750	11,600			
Si	786	1580	3230	4360	16,100		
P	1012	1900	2910	4960	6270	22,200	
S	1000	2250	3360	4560	7010	8500	27,100
Cl	1251	2300	3820	5160	6540	9460	11,000
Ar	1521	2670	3930	5770	7240	8780	12,000

- Notice the large increase after the last valence electron is removed. This chart can be used to determine the number of valence electrons in an atom of an element.

Electronegativity - the tendency of a bonded atom to attract shared electron to itself. (3.2.4)

Calculated from ionization energy and electron affinity.

Trends:

- **Top to bottom - electronegativity decreases**
- **Left to Right - electronegativity increases (excluding noble gases)**